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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent of:

Terrence C. Pearson

Patent No.: U.S. 6,953,546

Issued: October 11, 2005

For: **PLASTIC EXPULSION PROCESS FOR FORMING HOLLOW TUBULAR PRODUCTS**

Attorney Docket No.: PMT 0115 R

SUBMISSION OF PRIOR ART UNDER 35 U.S.C. §301 AND 37 C.F.R. §1.501

Commissioner for Patents
U.S. Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The undersigned herewith submits in the above identified patent the following prior art (including copies thereof) which is pertinent and applicable to the patent and is believed to have a bearing on the patentability of all 64 claims thereof.

CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8

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January 19, 2006	Robert C. J. Tuttle	/Robert C. J. Tuttle/
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- Abstract (English language) of Fukui *et al*, "Injection Molding Method For Hollow Product," Japanese patent application 05076584, filed April 2, 1994, Publication No. 06285895, published October 11, 1994. (Tab **A**)
- Fukui *et al*, "Injection Molding Method For Hollow Product," Japanese patent application 05076584, filed April 2, 1994, Publication No. 06285895, published October 11, 1994. (Tab **B**)
- Thomas, "Process For Pressure Assisted Molding Of Hollow Articles," U.S. Patent No. 6,716,387, issued April 6, 2004, from Appl. Ser. No. 10/085,372, filed February 28, 2002, claiming priority from Provisional Appl. Ser. No. 60/272,156, filed February 28, 2001. (Tab **C**)
- Berdan, "Multi-Venting Molding Apparatus," U.S. Patent No. 5,824,261, issued October 20, 1998, from Appl. Ser. No. 677,947, filed July 10, 1996. (Tab **D**)
- Kaneshi *et al*, "Mold Apparatus For Process Injection Molding," U.S. Patent No. 5,639,417, issued June 17, 1997, from Appl. Ser. No. 463,268, filed January 5, 1995. (Tab **E**)

Fukui et al - Japanese Publication No. 06285895

This prior art reference is not of record in the Pearson '546 patent. It is pertinent for at least the reasons it shows many of the apparatus limitations and process steps recited in the 64 process claims of the Pearson '546 patent. Claim 1 of the Pearson '546 patent is representative.

Fukui *et al* clearly meets the preamble of claim 1 — ***A process for injection molding a hollow plastic tubular article*** . . . .

Fukui *et al* meets the ***first injecting*** step, including the apparatus limitations recited in that step. Figure 1 of Fukui *et al* shows injection of plastic to substantially fill a mold cavity. (Fig 1(3)) The Fukui *et al* mold cavity has a cone-shaped inlet portion, apparent in Figures 1, 9, 13 and 14.

Fukui *et al* meets the ***second injecting*** step, including injecting pressurized gas into the mold cavity at the apex, apparent in Figure 1(4), 9, 13, and 14(d).

Fukui *et al* implicitly meets the ***holding*** step in that holding the pressure of the gas and plastic for a predetermined amount of time is a step common to all forms of gas-assisted plastic injection molding to permit the walls of the hollow molded article to "set-up" in the mold cavity prior to expulsion of fluent resin in the center of the plastic mass in the cavity. *See* Figures 1(4), 9, 13(2), and 14(4), all of which show the walls of the hollow molded article to be self-sustaining at the time of resin expulsion.

Fukui *et al* meets the ***allowing*** step reciting the expulsion of a portion of the plastic material into a secondary cavity coupled to the mold cavity. This is plainly evident in Figures 1(3) and 1(4) of Fukui *et al* showing expulsion of a portion of the plastic material into a secondary cavity defined by the interior of the retractable float.

Other embodiments of Fukui *et al* show subsidiary claim elements of Pearson '546, *e.g.*, the "apex" at the exit end of the mold cavity, in Figure 7, compares to claim 4 of the Pearson '546 patent. Other details recited in other dependent claims of the Pearson '546 patent are conventional and do nothing to impart patentability.

__Thomas '387__

Thomas '387 is §102(e) prior art based on the February 28, 2001 priority filing date of its underlying provisional application. This prior art reference is not of record in the Pearson '546 patent.

Thomas '387 discloses much of the claimed matter of Pearson '546. The claim 1 step of plastic injection "to at least substantially fill said mold cavity," is clearly taught in Thomas '387, col. 4, lines 42-44 ("Plastic delivery preferably continues until mold cavity 20 is packed to the greatest pressure possible by the present plastic injection process.") The claim 1 ***holding*** step is described in Thomas '387, col. 5, lines 5 - 7 (". . . it is preferred to maintain the pressure within the part for 2 to 10 seconds after injection.") The claim 1 step of expulsion of a portion of the plastic material into a secondary cavity coupled to the mold cavity, is evident in Thomas '387, Figure 2, where the mold cavity 20 is connected by a conduit 14 to a secondary cavity 16. The claim 4 step of expulsion of resin backwardly from the mold cavity is likewise shown in Thomas '387, Figure 2. The claim 7 apparatus limitation of a valve member in the conduit connecting the mold cavity with a secondary cavity is shown by valve 25 in Figure 1 of the Thomas '387 patent. Most every other claim element of Pearson '546 is a conventional implementation detail, not an inventive addition.

__Berdan '261__

Berdan '261 is §102(b) prior art based on its October 20, 1998 issue date. This prior art reference is not of record in the Pearson '546 patent.

Berdan '261 shows virtually all the process steps of Pearson '546, less only the application-specific apparatus limitations of molding tubular products.

__Kaneishi et al '417__

Kaneshi *et al* '417 is §102(b) prior art based on its June 17, 1997 issue date. This prior art reference is not of record in the Pearson '546 patent. Kaneshi *et al* '417 shows all essential steps of molding tubular products with fluid assistance, including the of a mold cavity with an "apex" shape, in Figures 12 - 17 and 26 - 31. It would be obvious to combine Kaneishi *et al* '417 with any other reference that discloses resin expulsion into a secondary cavity to realize the processes of claims 1 - 64 of the Pearson '546 patent.

Separately, it is known in the plastics industry that Cinpres Gas Injection Ltd. (the assignee of the Pearson '546 patent) and Mitsubishi Gas Chemical Company, Inc. (the assignee of the Kaneishi *et al* '417 patent) have had a long-standing licensor-licensee relationship. *See* http://www.m-ep.co.jp/mep-en/topics/t010401/040101.htm.

Respectfully submitted,

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CERTIFICATE OF SERVICE

I hereby certify on this 20th day of January, 2006, that a true and correct copy of the foregoing:

SUBMISSION OF PRIOR ART UNDER 35 U.S.C. §301 AND 37 C.F.R. §1.501

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A.

(19) JAPANESE PATENT OFFICE

PATENT ABSTRACTS OF JAPAN

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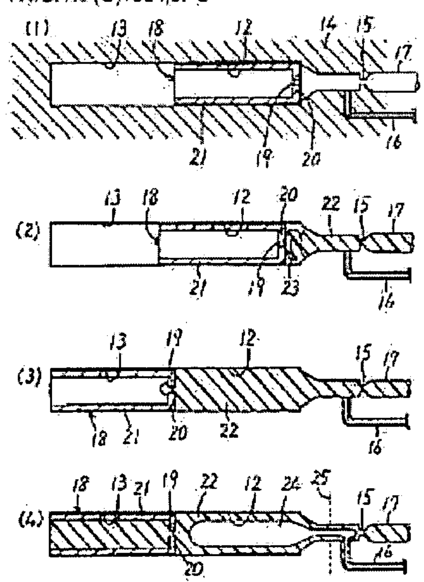
(54) INJECTION MOLDING METHOD FOR HOLLOW PRODUCT

(57) Abstract:

PURPOSE: To obtain a hollow product of excellent quality by preventing jetting of a plastic molding material which easily occurs at an initial stage of injecting in a method for injection molding the product by injecting fluid in the material at the stage of injection molding the product.

CONSTITUTION: The method for injection molding a hollow product comprises the steps of (1) disposing a float 18 in a main cavity 12 for specifying an inner surface correlative to a profile shape of the product to be obtained, (2) injecting a plastic molding material 22 toward the cavity 12 through a gate 15, (3) moving the float 18 toward an auxiliary cavity 13 while colliding the material 22 with a piston 20 until a space forming part 21 reaches an end of the cavity 13, and then (4) casting fluid through a fluid supply passage 16, forming a hollow part 24 and feeding excess material 22 from a hole 19 to the cavity 13 side.



B.

(19)日本国特許庁（JP）　(12) 公開特許公報（A）　(11)特許出願公開番号

特開平6－285895

(43)公開日　平成6年(1994)10月11日

(51)Int.Cl.⁵	識別記号	庁内整理番号	FI	技術表示箇所
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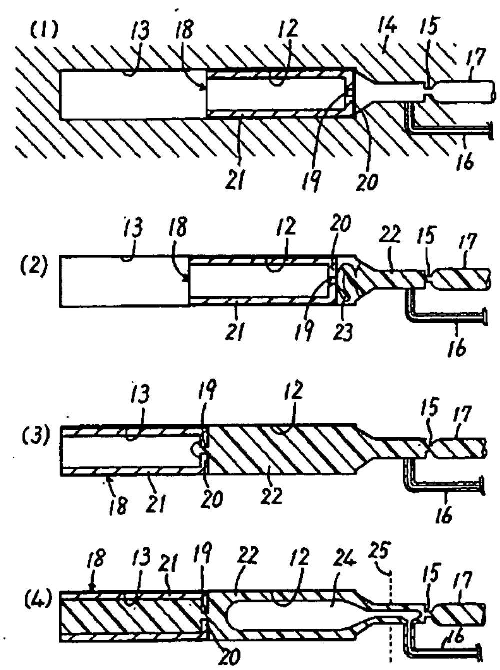
(54)【発明の名称】　中空品の射出成形方法

(57)【要約】

【目的】　塑性成形材料の射出成形の段階で、その内部に流体を注入することにより、中空品を得る射出成形方法において、射出の初期の段階で発生しやすい塑性成形材料のジェッティングを防止して、良好な品質の中空品を得る。

【構成】　（１）得ようとする中空品の外形状に相関する内面を規定する主キャビティ１２内にフロート１８を配置し、（２）ゲート１５を通して、塑性成形材料２２を主キャビティ１２に向かって射出し、これをピストン部２０に衝突させながら、（３）空間形成部２１が補助キャビティ１３の終端に達するまでフロート１８を補助キャビティ１３方向へ移動させた後、（４）流体供給経路１６を通して、流体を注入し、中空部２４を形成するとともに、余った塑性成形材料２２を穴１９から補助キャビティ１３側へ流出させる。



【特許請求の範囲】

【請求項１】　得ようとする中空品の外形状に相関する内面を規定する主キャビティおよび前記主キャビティに連なる補助キャビティを有するとともに、前記主キャビティの、前記補助キャビティが位置する側とは逆の端部において、前記主キャビティに連通するゲートおよび流体供給経路が設けられた金型を用意し、
前記主キャビティから前記補助キャビティまで移動可能であり、穴が設けられたピストン部および前記ピストン部の一方側に空間を与えるようにピストン部に連結される空間形成部を備えるフロートを用意し、
前記中空品の材料となる塑性成形材料を用意し、
前記フロートを、前記ピストン部が前記ゲート側に向きかつ前記空間形成部が前記補助キャビティ側に向くように、前記主キャビティ内に配置し、
その状態で、前記ゲートを通して、前記塑性成形材料を前記主キャビティに向かって射出し、それによって、射出された塑性成形材料を前記ピストン部に衝突させるとともに、前記空間形成部が前記補助キャビティの終端に達するまで前記フロートを前記補助キャビティ方向へ移動させ、
次いで、前記流体供給経路を通して、流体を前記主キャビティ内の前記塑性成形材料の内部に注入し、それによって、前記塑性成形材料の内部に中空部を形成するとともに、前記流体の注入により前記主キャビティ内で余剰となった前記塑性成形材料を前記ピストン部の穴から前記補助キャビティ側へ流出させる、各工程を備える、中空品の射出成形方法。

【請求項２】　得ようとする中空品の外形状に相関する内面を規定する主キャビティおよび前記主キャビティに連なる補助キャビティを有するとともに、前記主キャビティの、前記補助キャビティが位置する側とは逆の端部において、前記主キャビティに連通するゲートおよび流体供給経路が設けられた金型を用意し、
前記主キャビティから前記補助キャビティまで移動可能なフロートを用意し、
前記中空品の材料となる塑性成形材料を用意し、
前記フロートを前記主キャビティ内に配置し、
その状態で、前記ゲートを通して、前記塑性成形材料を前記主キャビティに向かって射出し、それによって、射出された塑性成形材料を前記フロートに衝突させるとともに、前記フロートを前記補助キャビティ方向へ終端にまで達しない程度に移動させ、
次いで、前記流体供給経路を通して、流体を前記主キャビティ内の前記塑性成形材料の内部に注入し、それによって、前記塑性成形材料の内部に中空部を形成するとともに、前記流体の注入量に相当する体積を前記主キャビティ側に与えるべく前記フロートを前記補助キャビティ方向へさらに移動させる、各工程を備える、中空品の射出成形方法。

【請求項３】　前記フロートは、穴が設けられたピストン部および前記ピストン部の一方側に空間を与えるようにピストン部に連結される空間形成部を備え、
前記フロートを前記主キャビティ内に配置する工程では、前記フロートを、前記ピストン部が前記ゲート側に向きかつ前記空間形成部が前記補助キャビティ側に向くように配置し、
前記流体を注入する工程では、前記塑性成形材料の一部を前記ピストン部の穴から前記補助キャビティ側へ流出させる、請求項２に記載の中空品の射出成形方法。

【請求項４】　前記フロートは、得ようとする中空品の外形状の一部を与える形状を有している、請求項１ないし３のいずれかに記載の中空品の射出成形方法。

【請求項５】　前記塑性成形材料は、熱可塑性樹脂である、請求項１ないし４のいずれかに記載の中空品の射出成形方法。

【請求項６】　前記塑性成形材料は、セラミック粉末とバインダとの混練物である、請求項１ないし４のいずれかに記載の中空品の射出成形方法。

【請求項７】　前記塑性成形材料は、金属粉末とバインダとの混練物である、請求項１ないし４のいずれかに記載の中空品の射出成形方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】この発明は、中空品の射出成形方法に関するもので、特に、中空品における中空部を形成するため、射出成形段階において塑性成形材料の内部に流体を注入する工程を備える、中空品の射出成形方法に関するものである。

【０００２】

【従来の技術】この発明にとって興味ある中空品の一例が図２および図３に示されている。図２は、斜視図であり、図３は、図２の線ＩＩＩ－ＩＩＩに沿う断面図である。

【０００３】図２および図３に示す中空品１は、特殊なランプの封入管として用いられるものであり、耐熱性が要求されることから、たとえばセラミックから構成される。このような中空品１を能率的に得るため、近年、一体的な射出成形を適用する試みがなされている。

【０００４】図１４は、上述した中空品１を得るための従来の射出成形方法に含まれる代表的な工程を順次示している。

【０００５】まず、図１４（１）に示すように、中空品１の外形状に相関する内面を規定するキャビティ２を有する金型３が用意される。金型３には、キャビティ２に連通するゲート４および流体供給経路５が設けられている。ゲート４には、ランナ６が連なっている。

【０００６】次に、図１４（２）に示すように、キャビティ２内に、たとえばセラミック粉末とバインダとの混練物からなる塑性成形材料７が射出され、この射出工程

は、図１４（３）に示すように、キャビティ２内に未充填分８が残る段階で終了される。

【０００７】次に、塑性成形材料７が未だ固化しないうちに、図１４（４）に示すように、塑性成形材料７の内部に、流体供給経路５を通して、たとえば窒素ガスのような流体が注入される。この流体の注入により、塑性成形材料７の内部に中空部９が形成されるとともに、塑性成形材料７は、キャビティ２内の未充填分８にまで行き渡る。

【０００８】次に、塑性成形材料７が固化したとき、金型３から取出され、図１４（４）において破線で示す切断線１０に沿って切断される。このようにして、図２および図３に示した中空品１のための未焼成成形体が得られる。この未焼成成形体は、次いで、脱脂され、その後、焼成され、中空品１が得られる。

【０００９】

【発明が解決しようとする課題】上述した従来の射出成形方法では、図１４（２）に示すように、塑性成形材料７の射出の初期の段階において、ジェッティング１１を発生しやすい。このジェッティング１１は、比較的速く固化される傾向にあるため、キャビティ２内での塑性成形材料７の流動むらの原因となる。したがって、得られた中空品１の外観不良を引起こしたり、中空部９の大きさまたは形状を製品間においてばらつかせたり、中空部９を偏心させたりすることがある。

【００１０】それゆえに、この発明の目的は、上述したようなジェッティングの発生を有利に防止して、得られた中空品の外観を良好なものとすることができるとともに、中空部を偏在させることなく安定的に形成することができる、中空品の射出成形方法を提供しようとすることである。

【００１１】

【課題を解決するための手段】この発明は、簡単に言えば、上述したジェッティングの発生を防止するため、フロートを用い、このフロートを金型のキャビティ内に配置した状態で射出成形を行なうことを特徴としている。

【００１２】より詳細には、この発明では、得ようとする中空品の外形状に相関する内面を規定する主キャビティおよび主キャビティに連なる補助キャビティを有するとともに、主キャビティの、補助キャビティが位置する側とは逆の端部において、主キャビティに連通するゲートおよび流体供給経路が設けられた金型と、主キャビティから補助キャビティまで移動可能であり、穴が設けられたピストン部およびピストン部の一方側に空間を与えるようにピストン部に連結される空間形成部を備えるフロートと、中空品の材料となる塑性成形材料とが、それぞれ、用意される。上述したフロートは、ピストン部がゲート側に向きかつ空間形成部が補助キャビティ側に向くように、主キャビティ内に配置される。その状態で、ゲートを通して、塑性成形材料が主キャビティに向かって射出され、それによって、射出された塑性成形材料をピストン部に衝突させるとともに、空間形成部が補助キャビティの終端に達するまでフロートが補助キャビティ方向へ移動される。次いで、流体供給経路を通して、流体が主キャビティ内の塑性成形材料の内部に注入される。これによって、塑性成形材料の内部に中空部が形成されるとともに、流体の注入により主キャビティ内で余剰となった塑性成形材料は、ピストンの穴から補助キャビティ側へ流出される。

【００１３】この発明は、また、次のように変更することもできる。すなわち、フロートを主キャビティ内に配置した状態で、ゲートを通して、塑性成形材料を主キャビティに向かって射出するとき、フロートを補助キャビティ方向へ移動させるが、その移動が補助キャビティの終端にまで達しないようにされる。そして、流体供給経路を通して、流体を塑性成形材料の内部に注入するとき、流体の注入量に相当する体積を主キャビティ側に与えるべくフロートが補助キャビティ方向へさらに移動される。

【００１４】上述した後者の方法では、フロートは、前者の方法で用いられたように、穴が設けられたピストン部およびピストン部の一方側に空間を与えるようにピストン部に連結される空間形成部を備えていても、このような穴を持たないものであってもよい。なお、この後者の方法において、前者の方法で用いられたフロートと同様のものを用い、同様の態様で主キャビティ内に配置する場合には、流体を注入する工程で、塑性成形材料の一部は、ピストンの穴から補助キャビティ側へ流出される。

【００１５】この発明で用いられるフロートは、得ようとする中空品の外形状の一部を与える形状を有していてもよい。

【００１６】また、この発明で用いられる塑性成形材料は、前述したセラミック粉末とバインダとの混練物であっても、金属粉末とバインダとの混練物であっても、セラミック粉末および金属粉末とバインダとの混練物であっても、さらには、熱可塑性樹脂であってもよい。

【００１７】

【作用】この発明において、フロートは、塑性成形材料の射出の初期の段階で塑性成形材料に衝突し、この段階で生じようとするジェッティングの成長を抑制する。

【００１８】

【発明の効果】したがって、この発明によれば、ジェッティングが原因となって引起こされるキャビティ内での塑性成形材料の流動むらを防止することができる。その結果、得られた中空品の外観不良を防止できるとともに、中空部を偏在させることなく安定的に形成することができる。

【００１９】特に、前述した前者の方法によれば、塑性成形材料を射出するとき、空間形成部が補助キャビティ

の終端に達するまでフロートが補助キャビティ方向へ移動される。すなわち、塑性成形材料の射出を終えた段階で、得ようとする中空品の外表面を与える塑性成形材料のスキン層のすべてが一挙に形成される。そのため、前述した後者の方法では生じる可能性のあるヘジテーションマークの発生を有利に防止することができる。

【0020】また、フロートとして、穴が設けられたピストン部およびこれに連結される空間形成部を備えるものを用い、流体を注入する工程において、塑性成形材料の一部を穴から補助キャビティ側へ流出させることを行なえば、得られた中空品の中空率をより高めることができる。

【0021】また、この発明で用いられるフロートは、主キャビティに向かって射出された塑性成形材料から受ける圧力によって補助キャビティに向かって移動される。言換えると、フロートを所望のごとく移動させるための特別な駆動手段を必要としない。そのため、金型の構造が複雑にならず、安価にこの発明による射出成形方法を採用することができる。

【0022】

【実施例】図1は、この発明の一実施例に含まれる代表的な工程を順次示している。この実施例は、前述した図2および図3に示した中空品1の射出成形方法に向けられている。

【0023】まず、図1（1）に示すように、得ようとする中空品1の外形状に相関する内面を規定する主キャビティ12および主キャビティ12に連なる補助キャビティ13を有する金型14が用意される。この実施例では、主キャビティ12と補助キャビティ13とが互いに等しい断面形状を有しているが、以下に説明する工程の実施を可能とする限り、主キャビティ12と補助キャビティ13とは互いに異なる断面形状を有していてもよい。金型14には、また、主キャビティ12の、補助キャビティ13が位置する側とは逆の端部において、主キャビティ12に連通するゲート15および流体供給経路16が設けられている。ゲート15には、さらに、ランナ17が連なっている。

【0024】図1（1）～（4）には、また、フロート18が図示されている。フロート18は、単独で、図4および図5に示されている。図4は、斜視図であり、図5は、図4の線Ｖ－Ｖに沿う断面図である。フロート18は、穴19が設けられたピストン部20、およびピストン部20の一方側に空間を与えるようにピストン部20に連結される空間形成部21を備える。この実施例では、空間形成部21は、円筒状をなしている。フロート18は、図1（1）～（3）を参照すればわかるように、主キャビティ12から補助キャビティ13まで移動可能である。なお、フロート18の外周面とキャビティ12および13の内周面とは、わずかな隙間を形成していても、全周にわたって互いに接触していてもよい。フロート18の移動に際して及ぼされる抵抗の所望の大きさに応じて、フロート18の外周面とキャビティ12および13の内周面との接触圧力を設定すればよい。また、フロート18が主キャビティ12から補助キャビティ13まで移動するときの抵抗をさらに大きくしたい場合には、図示しないが、たとえば圧縮ばねを、フロート18と補助キャビティ13の端部との間に配置することもできる。

【0025】上述したフロート18は、図1（1）に示すように、そのピストン部20がゲート15側に向きかつ空間形成部21が補助キャビティ13側に向くように、主キャビティ12内に配置される。

【0026】その状態で、図1（2）に示すように、ゲート15を通して、塑性成形材料22が主キャビティ12に向かって射出される。この射出の初期の段階において、発生し得るジェッティング23は、ピストン部20に衝突することにより、直ちに消去される。この塑性成形材料22が与える圧力により、フロート18は、補助キャビティ13方向へ移動する。そして、塑性成形材料22の射出は、図1（3）に示すように、空間形成部21が補助キャビティ13の終端に達するまでフロート18が補助キャビティ13方向へ移動したときに終了される。このとき、図1（3）に示すように、塑性成形材料22のごく一部は、ピストン部20の穴19から補助キャビティ13側へ漏れることもある。

【0027】次に、図1（4）に示すように、流体供給経路16を通して、たとえば窒素ガスのような流体が主キャビティ12内の塑性成形材料22の内部に注入される。これによって、塑性成形材料22の内部に中空部24が形成されるとともに、流体の注入により主キャビティ12内で余剰となった塑性成形材料22がピストン部20の穴19から補助キャビティ13側へ流出される。なお、図1（4）では、塑性成形材料22が、フロート18の空間形成部21によって形成される空間をすべて埋めているが、塑性成形材料22は、この空間をすべて埋める必要はない。

【0028】図1（4）に示した工程を終えた後、塑性成形材料22が固化される。この固化された塑性成形材料22は、フロート18とともに、金型14から取出され、破線で示す切断線25に沿って切断される。また、フロート18が、その内部にある塑性成形材料22とともに除去される。これによって、図2および図3に示した中空品1が得られる。なお、フロート18の除去は、塑性成形材料22の部分での切断によっても、フロート18の強制的な引離しによってもよい。後者の場合、穴19内に位置していた塑性成形材料22が中空品1側に突起として残されることもあるが、このような突起は、以後の工程において、切断または研磨等により容易に除去することができる。

【0029】用いられた塑性成形材料22が、熱可塑性

樹脂である場合には、そのまま、中空品1を製品として用いることができる。他方、塑性成形材料22が、セラミック粉末とバインダとの混練物、金属粉末とバインダとの混練物、またはセラミック粉末および金属粉末とバインダとの混練物である場合には、その後、脱脂および焼成工程に付され、製品としての中空品1が提供される。なお、これら脱脂および焼成工程において発生する分解ガスは、中空品1の外面からだけでなく、中空部24を規定する内面からも放出され、中空部24内に放出された分解ガスは、中空部24の端部の開口26から迅速に排出される。

【0030】以上述べた実施例において、フロート18に対して、得ようとする中空品1の外形状の一部を与える機能を持たせることもできることがわかる。以下に説明する図6ないし図9に示した実施例では、この機能をより積極的に働かせようとするものである。

【0031】この実施例は、図6および図7に示した中空品27を製造しようとするものである。図6は、中空品27の斜視図であり、図7は、図6の線ＶＩＩ－ＶＩＩに沿う断面図である。この実施例では、図8に示すような断面形状を有するフロート28が用いられる。フロート28は、穴29が設けられたピストン部30、およびこのピストン部30の一方側に空間を与えるようにピストン部30に連結される円筒状の空間形成部31を備えるだけでなく、ピストン部30において、副キャビティ32を形成している。

【0032】図9は、前述した図1（4）に示す工程に相当する工程を示している。なお、図9において、図1に示した要素に相当する要素には同様の参照符号を付し、重複する説明は省略する。図9において、塑性成形材料22の内部に流体供給経路16を通して注入された流体は、フロート28の副キャビティ32内にまで至る中空部33を形成する。塑性成形材料22が固化され、金型14から取出され、フロート28が除去された後、破線で示す2本の切断線34および35に沿って切断されたとき、図6および図7に示すような中空品27が得られる。この中空品27の一方端部36の外形状は、フロート28に形成された副キャビティ32によって与えられる。また、この中空品27では、中空部33の両端部に開口37および38が形成されている。

【0033】上述した実施例から理解されるように、この発明に係る射出成形方法によれば、そこに用いられるフロートの形状を変更するだけで、金型を共通に用いながら、異なる形状の中空品を容易に得ることができる。

【0034】この発明では、使用を終えたフロートは、好ましくは、そこに付着された塑性成形材料を除去して、再利用される。図10ないし図12にそれぞれ示したフロートは、このような使用後の塑性成形材料の除去をより容易に行なえるように考慮したものである。

【0035】図10に示したフロート39は、複数個の穴40が設けられたピストン部41、およびピストン部41の一方側に空間を与えるようにピストン部41に連結される空間形成部42を備える。空間形成部42は、シャフト部43とその端部に位置するフランジ部44とを備える。射出成形を終えたとき、塑性成形材料は、シャフト部43の周囲に付着するので、この塑性成形材料を容易に除去することができる。なお、図10（ｂ）に示すように、空間形成部42のシャフト部43とフランジ部44とを分離可能としておけば、塑性成形材料の除去がさらに容易になる。

【0036】図11に示したフロート45は、複数個の穴46が設けられたピストン部47、およびピストン部47の一方側に空間を与えるようにピストン部47に連結される空間形成部48を備える。空間形成部48は、断面Ｘ字状のシャフト部49とその端部に設けられたフランジ部50とを備える。フロート45の使用後において、塑性成形材料はシャフト部49の外表面に付着するが、このような塑性成形材料は容易に除去することができる。

【0037】図12に示したフロート51は、穴52が設けられたピストン部53、およびピストン部53の一方側に空間を与えるようにピストン部53に連結される円筒状の空間形成部54を備えており、前述したフロート18と類似する形状を有しているが、第1の部分55と第2の部分56とに分割可能なように構成されている。第1の部分55および第2の部分56は、それぞれ、対をなすスナップ係合部57および58を形成していて、これらスナップ係合部57および58が互いに係合することにより、第1の部分55および第2の部分56が一体化される。このフロート51では、使用後において、フロート18と同様、円筒状の空間形成部54内に塑性成形材料が残されるが、第1の部分55と第2の部分56とを互いに分離することにより、この塑性成形材料を容易に除去することができる。

【0038】図13は、この発明のさらに他の実施例を説明するためのものである。図13（1）および（2）は、前述した図1（1）および（2）に示した工程の後に実施される工程を示している。したがって、図13において、図1に示す要素に相当する要素には同様の参照符号を付し、重複する説明は省略する。

【0039】図1（1）および（2）にそれぞれ示した工程が順次実施された後、図13（1）に示した状態とされる。すなわち、ゲート15を通して、塑性成形材料22が主キャビティ12に向かって射出されるとき、フロート18が補助キャビティ13方向へ移動されるが、その移動が補助キャビティ13の終端にまで達しない段階で、塑性成形材料22の射出が終了される。

【0040】次いで、同じく図13（1）に示すように、流体供給経路16を通して、流体が塑性成形材料22の内部に注入される。この流体の注入によって、図1

３（２）に示すように、流体の注入量に相当する体積を主キャビティ１２側に与えるように、フロート１８が補助キャビティ１３方向へさらに移動される。このとき、好ましくは、フロート１８は、補助キャビティ１３の終端に達するまで移動される。

【００４１】図１３（２）においては、流体の注入の結果、塑性成形材料２２の一部がピストン部２２の穴１９から補助キャビティ１３側へ流出された状態が図示されている。この塑性成形材料２２の一部の流出は、必須ではなく、したがって、図１３に示した実施例では、フロート１８に穴１９が設けられる必要はない。しかしながら、穴１９が設けられていると、中空部２４の大きさを容易に大きくすることができるとともに、次のような効果も期待できる。

【００４２】すなわち、図１３（１）の工程で射出が終了される塑性成形材料２２の量のコントロールをそれほど厳密に行なわなくても、常に所望の形状を有する中空品１を得ることができる。なぜなら、塑性成形材料２２の一部を穴１９から補助キャビティ１３側へ流出させることができれば、図１３（１）の段階で射出された塑性成形材料２２の量のばらつきを、穴１９から流出される塑性成形材料２２の量によって吸収することができるからである。

【００４３】上述したいくつかの実施例において、流体供給経路１６を通して注入される流体としては、通常、たとえば窒素ガスのようなガスが用いられるが、他のガスまたは液体が用いられてもよい。

【００４４】また、上述した実施例で示した中空品１または２７は、この発明によって得られる中空品の一例にすぎず、金型に設けられる主キャビティおよび補助キャビティの形状を変更することにより、任意の形状の中空品を得ることができる。また、フロートの形状についても、主キャビティおよび補助キャビティの形状に応じて任意に変更することができる。

【図面の簡単な説明】

【図１】この発明の一実施例に含まれるいくつかのステップを順次示す断面図である。

【図２】図１に示した実施例により得ようとする中空品＊１を示す斜視図である。

【図３】図２の線ＩＩＩ－ＩＩＩに沿う断面図である。

【図４】図１に示したフロート１８を単独で示す斜視図である。

【図５】図４の線Ｖ－Ｖに沿う断面図である。

【図６】この発明の他の実施例によって得ようとする中空品２７を示す斜視図である。

【図７】図６の線ＶＩＩ－ＶＩＩに沿う断面図である。

【図８】図６および図７に示した中空品２７を得るために用いられるフロート２８を示す断面図である。

【図９】図８に示したフロート２８を用いて、図６および図７に示した中空品２７を得ようとする実施例における、図１（４）に相当する工程を示す断面図である。

【図１０】この発明のさらに他の実施例で用いられるフロート３９を示し、（ａ）は組立状態の斜視図であり、（ｂ）は分解状態の斜視図である。

【図１１】この発明のさらに他の実施例において用いられるフロート４５を示す斜視図である。

【図１２】この発明のさらに他の実施例において用いられるフロート５１を分解した状態で示す斜視図である。

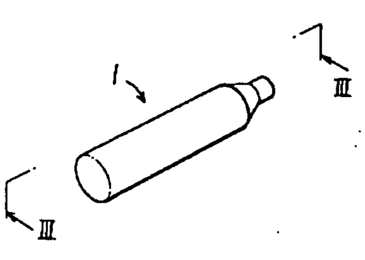
【図１３】この発明のさらに他の実施例に含まれる、図１（１）および（２）の工程の後に実施される工程を順次示す断面図である。

【図１４】従来の中空品の射出成形方法に含まれるいくつかのステップを順次示す断面図である。

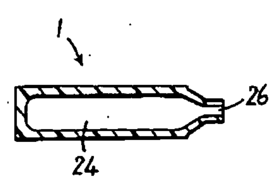
【符号の説明】

１，２７　中空品
１２　主キャビティ
１３　補助キャビティ
１４　金型
１５　ゲート
１６　流体供給経路
１８，２８，３９，４５，５１　フロート
１９，２９，４０，４６，５２　穴
２０，３０，４１，４７，５３　ピストン部
２１，３１，４２，４８，５４　空間形成部
２２　塑性成形材料
２４，３３　中空部

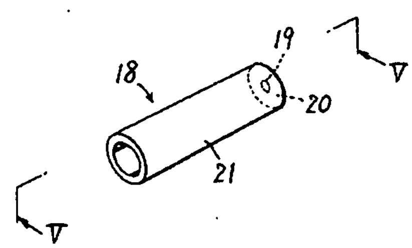
【図２】



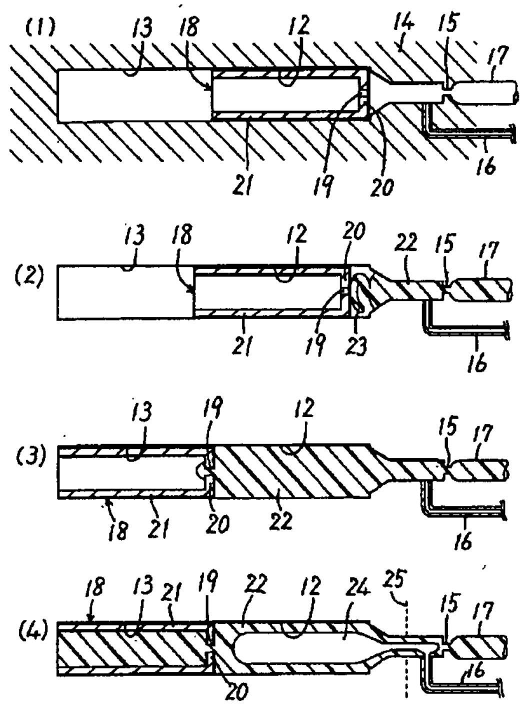
【図３】



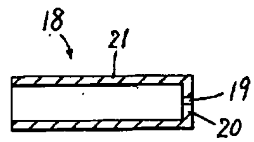
【図４】



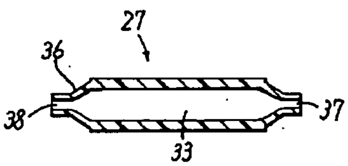
【図1】



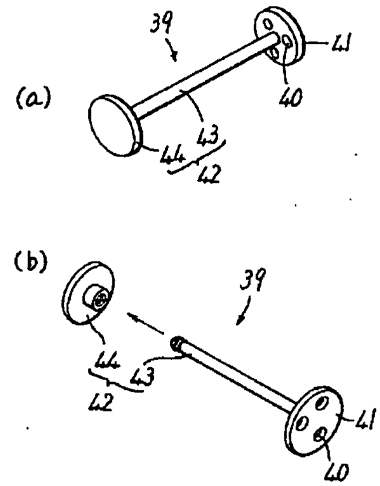
【図5】



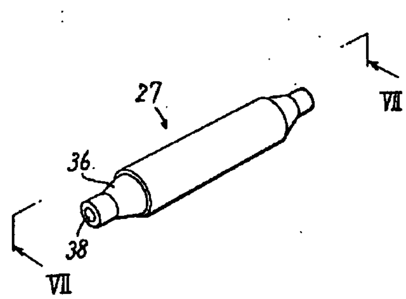
【図7】



【図10】



【図6】



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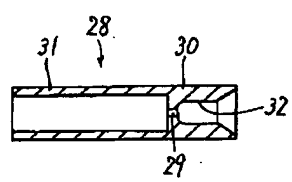

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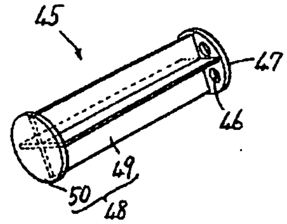

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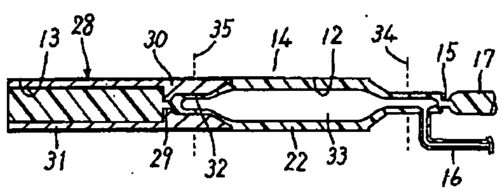

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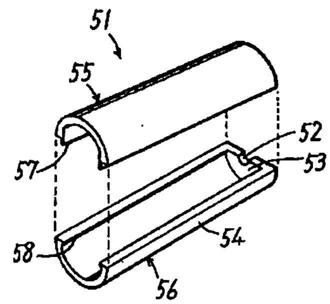
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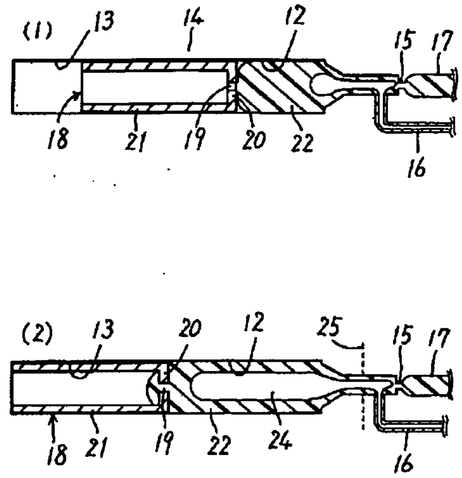
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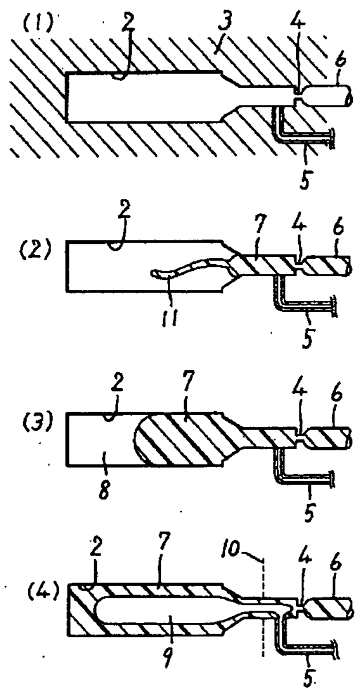
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(12) United States Patent
Thomas

(10) **Patent No.:** **US 6,716,387 B2**
(45) **Date of Patent:** **Apr. 6, 2004**

(54) **PROCESS FOR PRESSURE ASSISTED MOLDING OF HOLLOW ARTICLES**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **B29D 22/00**
(52) **U.S. Cl.** **264/572**
(58) **Field of Search** 264/572

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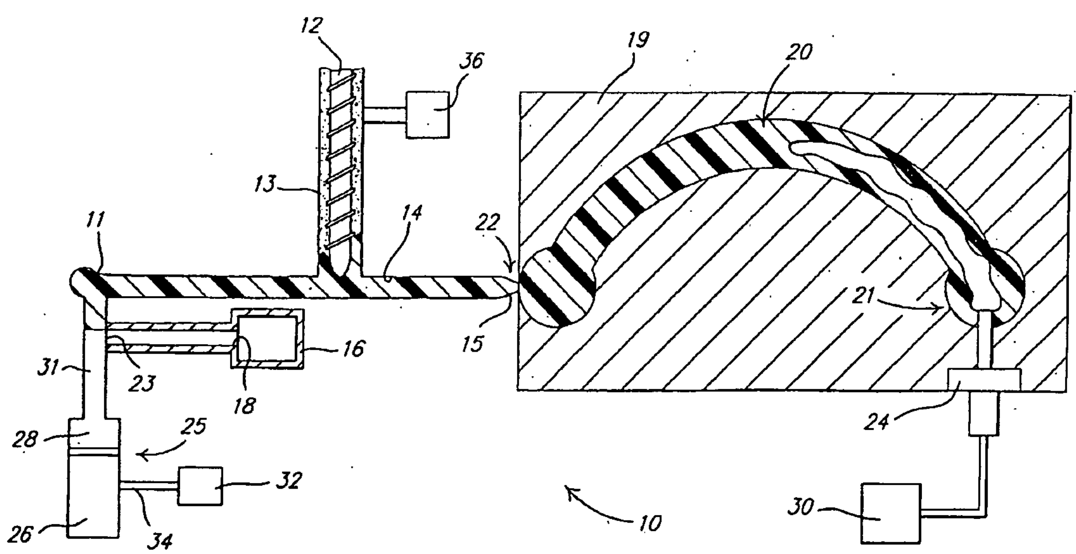
(57) **ABSTRACT**

The present invention provides a process for fluid assisted injection molding comprising the step of providing an injection molding apparatus having a mold body that defines a mold cavity. The process further comprises the steps of supplying a quantity of fluent plastic to the mold cavity, followed by injecting a fluid into the mold cavity. The fluid forms an expanding fluid pocket in the mold cavity, driving plastic to the furthest recesses of the mold and ensuring a smooth surface finish of the final molded product. A reservoir is selectively connectable to a plastic injection runner, and can be opened to the runner to receive molten plastic ejected by the introduction of the fluid to the mold cavity. When the reservoir is thusly connected, the pressure of the fluid forces the plastic through a supply passage, in a direction substantially opposite to its initial injection direction.

18 Claims, 2 Drawing Sheets



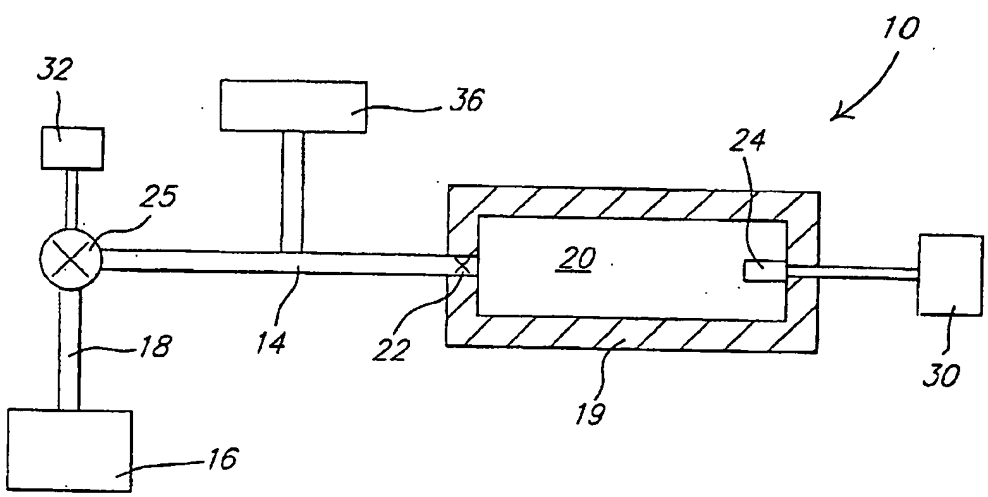


FIG. 1.

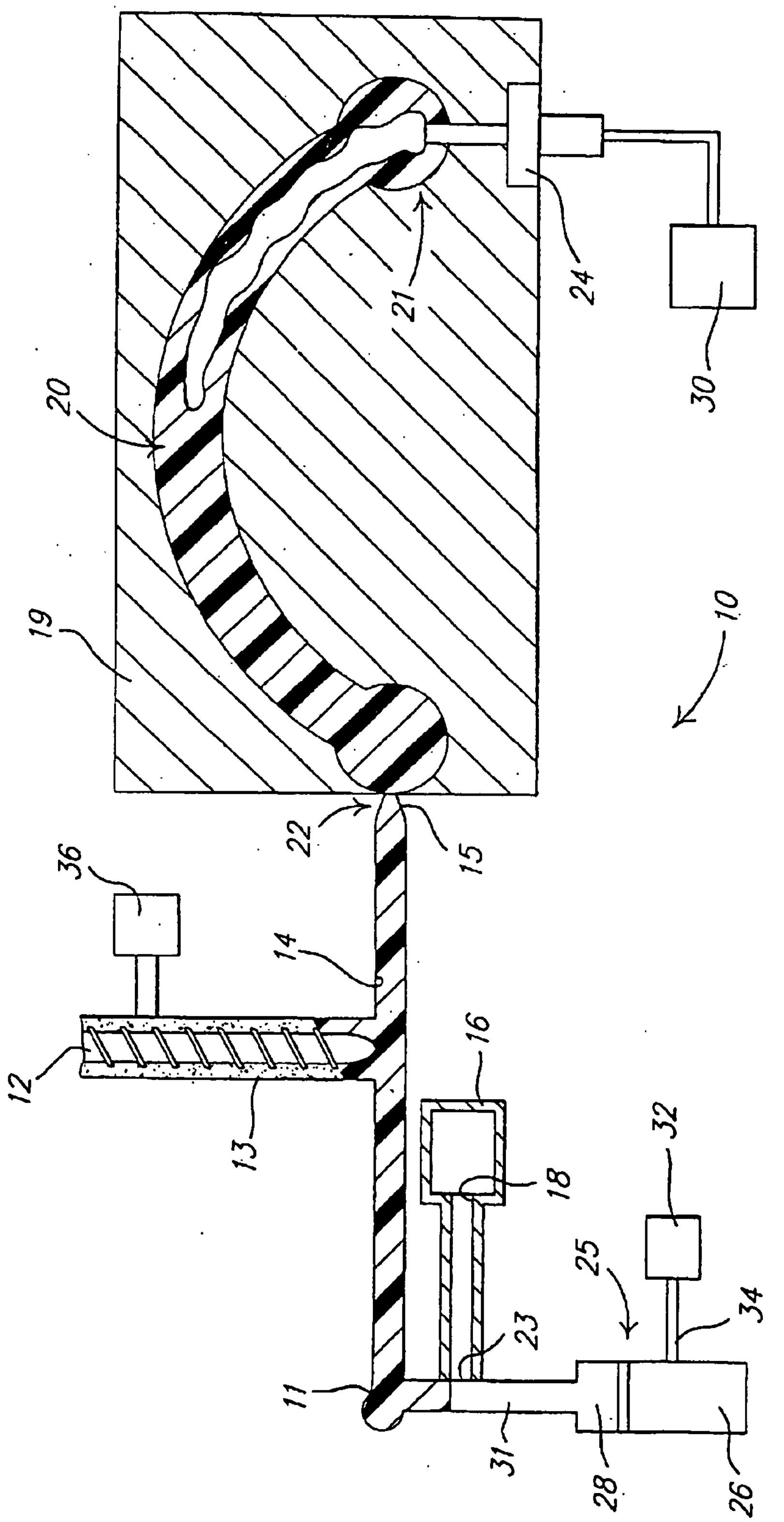


FIG. 2

PROCESS FOR PRESSURE ASSISTED MOLDING OF HOLLOW ARTICLES

This Application Claims the Priority of U.S. Provisional Application No. 60/272,156 Filed Feb. 28, 2001.

TECHNICAL FIELD

The present invention relates generally to fluid assisted injection molding processes, and more particularly to such a process utilizing an overfill reservoir selectively connectable to a fluent plastic supply line.

BACKGROUND OF THE INVENTION

There are a wide variety of gas or fluid assisted injection molding apparatuses and processes available in the art. Injection molding generally comprises injecting a molten plastic under pressure (usually by a screw feed injector) into a closed two piece cavity. When the part cools, the mold pieces are separated and the part removed. There are various references to specific pressure profiles to best implement the molding process, and a plethora of plastic injection molding machines commercially available.

Gas or fluid assisted injection molding generally involves injecting gas into the fluid plastic material either during or after plastic injection to create a hollow within the part. This reduces the weight of the part and the cost of material used. More importantly, pressurizing the interior of the part forces the fluid plastic against the mold surface as it cools. When plastics cools, it shrinks, and tends and pull away from the mold surface, leaving unsightly sink marks. The cooling of the plastic within the mold also reduces the pressure of the plastic within the mold. There are a variety of gas or fluid assist controllers and equipment commercially available.

There is another variation of the injection process known generally as overflow, overspill, spillovers or similar names. This process generally involves injecting more plastic material into the mold cavity than the cavity will hold, and allowing material to flow into reservoirs at the remote ends of the plastic flow path to receive the excess. If the reservoir locations are chosen properly, the plastic must fill every bit of the mold cavity before the reservoirs are filled, thus ensuring complete mold fill out. Again, molding equipment utilizing the overflow concept is commercially available.

Some combinations of overflow and fluid injection have been attempted, generally to speed the fill out process or to intentionally dispel fluid plastic from the part interior to create a hollow part. These processes have generally proven unreliable (poor repeatability). The typical combination process injects gas at or near the plastic inlet, pushing the plastic toward the overspill at the far end(s) of the mold cavity. This results in a flow of the cooling resin toward a small gate located at the opposite end of the cavity. When the resin cools, it is much less viscous and tends to resist flowing through the overspill gate. The plastic's resistance to shear also increases with the decrease in temperature, adding further resistance to travel through the overspill gate, and causing the resin flow to stall at the overspill entrance. This "blockage," or area of greater resistance to flow, can lead to or cause a number of problems or undesirable conditions. For example, this situation often prompts operators to utilize unnecessarily high gas injection pressures to move the resin through the overspill gate. Further, this undesired resistance may localize high gloss areas over the channel.

Typically, when confronted by the resistance of the cooling resin at the over-spill gate, the gas will in effect migrate to "thin wall" sections of the plastic part causing quality/function problems. This is like blowing up a balloon with thin spots, the thicker areas will not stretch, causing the thin section to overstretch. As a result, parts are characterized by an increase in the resin wall thickness as the gas moves from the hotter gate area at the point of gas injection (more pliable resin is moved along by the gas) to the relatively cooler area at the end of the gas channel/entrance of the overspill (less pliable resin stays in place and is less affected by the gas). Further, if the amount of plastic flowing into the overspill is reduced, the amount of space the gas will occupy at a given pressure is similarly reduced, thus yielding a part heavier than desired. Further still, the use of gas injection at/near the point of plastic injection creates a need to have greater or even excessive gas injection delay times to insure that the hotter resin around the gate/pin is cooled sufficiently that the molten resin will not be blown off the gas pin. Similarly, longer gas injection delay times would also be necessary to ensure that the hotter resin around the gate/pin is cooled sufficiently so that the molten resin will not "foam up" (become mixed with resin). The higher the gas pressure to be used, the longer the injection delay required to avoid these problems.

U.S. Pat. No. 5,204,051 to Jaroschek is entitled "Process For The Injection Molding Of Fluid-Filled Plastic Bodies." In Jaroschek, a, flowable plastic melt is first injected into a mold cavity. After cooling of the plastic melt along the mold cavity walls, a fluid is injected in a manner such that the still-melted center of the resulting plastic body is expelled into a side cavity. Jaroschek states that the process can be undertaken in such a way that fluent plastic is forced back toward the plastic supply by the incoming fluid. Thus, the molten plastic supply could serve as the side cavity for receipt of the expelled plastic; however, it is first necessary to lift the sprue away from its seat to allow the plastic to pass, leaving a quantity of plastic between the sprue body and its seat.

SUMMARY OF THE INVENTION

In one aspect, an injection molding apparatus is provided. The injection molding apparatus includes a cavity for forming a hollow molded plastic part, a source of fluent plastic fluidly connectable to the cavity, and a runner for supplying fluent plastic from the source to the cavity. At least one fluid injection pin is provided and is mounted to the mold body and connectable to a fluid source. A reservoir is also provided and is positioned remote from the cavity, the reservoir is selectively connectable to the runner via a sub-runner. Finally, a valve is positioned adjacent a mouth of the sub-runner. The valve is operable between a first state at which the reservoir is fluidly connected to the runner and a second state at which the reservoir is blocked from fluid communication with the runner.

In another aspect, a process for injection molding of fluid filled plastic bodies is provided. The process includes the steps of providing an injection molding apparatus having a mold body that defines a mold cavity, and a source of flowable plastic material fluidly connectable to the mold cavity with a supply passage. At least one reservoir is also provided and is fluidly connectable to the supply passage with a control valve. At least one fluid injection pin is also provided and is connectable to a fluid source. The process further includes the steps of injecting a quantity of flowable plastic into an interior of the mold cavity through the supply passage, and cooling part of the injected plastic along the walls of the mold cavity, providing an interior of flowable plastic melt. In addition, the process includes the step of selectively expelling at least a portion of the interior of

flowable plastic melt into the supply passage, and selectively expelling at least a portion of fluent plastic from the supply passage into the reservoir.

In yet another aspect, a method of forming a hollow injection molded plastic part is provided. The method includes the steps of providing a mold body having a mold cavity, connecting a source of fluent plastic to the mold cavity with a runner passage, and mounting at least one fluid injection pin to the mold body, and connecting the pin to a fluid source. The method further includes the steps of injecting a quantity of fluent plastic via the runner into the mold cavity, and injecting a quantity of fluid into the mold cavity, thereby expelling a portion of the quantity of fluent plastic to the runner, leaving a hollow plastic body around the periphery of the mold cavity. The method finally includes the step of selectively connecting the runner to a reservoir and expelling a quantity of fluent plastic to the reservoir.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a system level diagram of a pressure-assisted injection molding apparatus according to the present invention;

FIG. 2 is a partial sectioned side view of an apparatus similar to FIG. 1.

DETAILED DESCRIPTION

Referring to FIG. 1, there is shown a system level diagram of an injection molding apparatus **10** for undertaking a pressure-assisted injection molding process according to the present invention. Apparatus **10** preferably includes a mold body **19**, a fluent plastic source **36**, a reservoir **16**, and a fluid source **30**. Fluent plastic source **36** is connected via a runner **14** to mold cavity **20** for supplying fluent plastic thereto. A gate **22** having a restricted diameter preferably connects runner **14** to cavity **20**. A fluid injection pin **24**, which is fluidly connected to a fluid source **30**, extends into mold cavity **20**, and can deliver fluid into an interior of cavity **20** when desired. Runner **14** can also fluidly connect mold cavity **20** to reservoir **16**, which is positioned remotely from mold cavity **20**, via a sub-runner **18**. Fluid communication between reservoir **16** and runner **14** (and thus mold cavity **20**) is initiated and terminated with a control valve **25**. In the preferred embodiment, control valve **25** is hydraulically actuated with fluid from a hydraulic fluid source **32**, however, it should be appreciated that control valve **25** could be actuated by pneumatic, electromagnetic, or some other means.

Referring to FIG. 2, there is shown a partial sectioned side view of apparatus **10** similar to that illustrated in FIG. 1. Apparatus **10** preferably includes a conventional threaded-shaft sprue **12** positioned in a delivery shaft **13** for delivering molten plastic to the mold. It should be appreciated, however, that a different style of extruder, piston, or some other system for delivering molten plastic might be used. Shaft **13** is connected to runner **14**, which is preferably a substantially cylindrical passage having a tapered injection end **15** and an ejection end **17**. Injection end **15** is positioned adjacent gate **22** in mold body **19**. Mold body **19** is preferably metallic and has two separable halves (only one is illustrated), which when closed define mold cavity **20**. Mold cavity **20** is illustrated in FIG. 2 as generally tube-shaped, however, it should be appreciated that mold cavity **20** might have any of a great number of different shapes, depending on the desired shape of the part to be molded therein. Fluid injection pin **24** is preferably positioned at a downstream end **21** of mold cavity **20**, and extends partially into an interior of cavity **20**.

Runner **14** is preferably fluidly connectable to sub-runner **18** at its ejection end **17**. In the preferred embodiment, control valve **25** includes a hydraulically-controlled piston **28**. Piston **28** preferably has a control surface **29** exposed to fluid pressure in a hydraulic cylinder **26**, and a substantially cylindrical end portion **31**. Piston **28** has an extended position at which end portion **31** blocks an open end **23** of sub-runner **18**, blocking fluid communication between sub-runner **18** and runner **14**, thereby blocking fluid communication between cavity **20** and reservoir **16**. Piston **28** also has a retracted position at which end portion **31** does not block open end **23** and therefore allows fluid communication between sub-runner **18** and runner **14**, and can be moved between its two respective positions by controlling the hydraulic pressure supplied to chamber **26**. If desired, a biasing spring (not shown) may be positioned in chamber **26** to bias piston **28** toward its extended position.

When initiation of a typical pressure assisted injection molding cycle is desired, the separable halves of mold body **19** are closed and secured. Fluent plastic source **36** is preferably a conventional heated plastic supply, and delivers fluent plastic to sprue **12** in a conventional manner. In the embodiment shown in FIG. 2, sprue **12** is rotated to drive molten plastic through delivery shaft **13** and into runner **14**. At cycle initiation, hydraulic piston **28** should be held at its extended position, blocking fluid communication between runner **14** and reservoir **16**. The rotation of sprue **12** delivers molten plastic to runner **14** and substantially fills runner **14** relatively quickly, at which point the molten plastic begins to pass through gate **22**, filling cavity **20**. During the injection process, the heat and pressure of the plastic that follows through sprue **12** keeps the plastic in the runner fluid during the injection process. Further, the runner **14** itself becomes heated by the continuous flow of molten plastic and helps maintain the temperature of the molten plastic during subsequent cycles. As the plastic clears the gate, it rapidly loses pressure as it enters the mold cavity, and begins to cool. It is thus critical to quickly fill the mold cavity to ensure a smooth and even coverage of the mold surface. Plastic delivery preferably continues until mold cavity **20** is packed to the greatest pressure possible by the present plastic injection process. In other embodiments, as described below, however, plastic injection can be terminated prior to filling the cavity entirely.

Once cavity **20** has been packed to the desired condition, injection of a fluid under pressure through pin **24** can begin. In the preferred embodiment, a brief delay is allowed between the termination of plastic injection and the initiation of fluid injection, allowing the plastic to begin to solidify along the exterior mold surfaces, however, fluid injection may be initiated immediately after cessation of plastic injection if desired, or might even be initiated before plastic injection ends. There are myriad available pins for fluid injection, including Applicant's ANP-series gas pin. The initial injection pressure depends upon the size of the part, the mold, and the size of the desired hollow space. Since the initial pressure will occur at a point of substantial fill out, the hollow created by the fluid injection will be the result of: (1) the shrinkage in plastic; and (2) the more complete fill out or packing of plastic into the mold caused by the increased pressure. The fluid most commonly used for the initial pressurization is compressed air, however, it is contemplated that other fluids, for example compressed nitrogen gas or water, may be preferred for particular molding applications. The fluid may be heated, chilled, or injected at ambient

temperatures. The injected fluid creates an expanding pocket or hollow in the mold, and the consequent rising pressure of the fluid drives plastic to the furthest recesses of the mold, forcing the plastic relatively tightly against the interior mold surfaces. In order to ensure an even part thickness and to maximize the quality of the surface finish, it is preferred to maintain the pressure within the part for 2 to 10 seconds after injection. It should be appreciated, however, that the pressure might be lowered or raised during this dwell portion of the cycle. Further, additional fluid may be injected to maintain cavity pressure lost due to plastic cooling and shrinkage.

During the filling of cavity **20**, the injected plastic begins to cool, resulting in partial hardening of the plastic adjacent the internal mold surfaces, yet leaving a flowable, molten plastic melt portion in the center of the molded article. In addition to cooling and hardening of the plastic at the exterior of the molded article, the melt portion in the center of the mold undergoes a degree of cooling. In the embodiment shown in FIG. **2**, once mold cavity **20** is substantially filled, the plastic which has remained in the mold longest, and thus undergone the greatest degree of cooling is the plastic filling the mold cavity closest to its downstream end **21**. Consequently, the downstream volume of the interior melt portion is slightly cooler and more viscous than the volume closer to gate **22**.

Because valve **25** preferably remains closed during plastic and fluid injection, the pressure in the molding apparatus can build considerably during injection of fluid. When the desired dwell time has elapsed, valve **25** is hydraulically actuated, opening fluid communication between runner **14** and sub-runner **18**. Because mold cavity **20** is under pressure from the injected fluid, the opening of valve **25** causes the molten plastic in runner **14** to begin to flow through sub-runner **18** toward reservoir **16**. As plastic flows through runner **14**, molten plastic (the interior melt) begins to flow from cavity **20** through gate **22**, and thenceforth to runner **14**. In a preferred embodiment, the volume of runner **14** is approximately equal to or greater than the volume of molten plastic expelled from cavity **20**. There are at least two advantages in bleeding off the fluid plastic by opening the run-off reservoir after pressure has been built up in the mold cavity. First, the movement of fluid plastic material is initiated after a cavity is established within the part. This results in a more even wall thickness of the molded part. Further, this results in a more laminar flow of the fluid plastic core, which results in more uniform part production. The distinction is somewhat like comparing the un-pressurized bleeding of fluid lines to purging the lines with a burst of air. Although the interior surface quality of the molded part is not critical, the purpose is to leave as uniform a deposit of plastic as possible upon the mold surface. The second advantage is that the dwell time allows the part surface to set up before the remaining fluid plastic is bled out, and thus the part surface is more resistant to the shear forces resulting from the flow of the fluid plastic toward the runner.

Once the desired quantity of plastic has been evacuated to reservoir **16**, valve **25** is closed, allowing runner **14** to become packed with any additional plastic ejected from the mold. It is preferable to locate the fluid injection pin or pins at a point or points in the mold most downstream of the gate, while still allowing for a desired part thickness, as the drawing Figures illustrate, although it should be appreciated that the pin might be positioned elsewhere. Because the preferred arrangement ejects the interior melt from mold cavity **20** in an upstream direction, i.e. toward the plastic supply, the lesser-cooled portion of the melt positioned closest to gate **22** is ejected first, with the more downstream portion of the melt ejected later. Thus, with the hotter and less-viscous plastic ejected first, initiation of ejection is easier than in systems that eject the cooler plastic first. This is particularly advantageous where, as in the present invention, the bleeding of fluid plastic is delayed to allow for adequate surface curing of the part, thus decreasing the fluidity of the plastic on the interior of the part, particularly at the points remote from the gate. Bleeding the most fluid plastic from the mold first is the most efficient way to remove the greatest amount of still cooling fluid plastic and facilitates plastic ejection without the need for excessively high fluid injection pressures. This also reduces the chance of more-cooled/less-fluid plastic impeding the flow of less-cooled/more-fluid plastic toward and through the gate. Since the pin(s) **24** is/are located at the remote end(s) of the cavity, there is also less chance of flashing or fluid plastic encroachment into the pin. Further still, when runner **14** is packed with the ejected plastic material, the cooler and more viscous portion of the melt will occupy the upstream side of gate **22**. Thus, upon opening of the respective halves of mold body **20** to remove the molded part, the plastic immediately adjacent the mold cavity (at runner **14**'s injection end **15**) is relatively cooler and firmer than the plastic at the opposite end **17** of runner **14**. This partially cooled plastic separates more cleanly from the molded part than hotter, less viscous plastic would, resulting in a cosmetically superior molded part.

It should be appreciated that the fluid may be injected via pin **24** prior to opening of valve **25**, then halted, allowing the built-up pressure to drive plastic from the mold when valve **25** is opened. Alternatively, fluid may be injected before opening valve **25**, as well as after the valve is opened. A third alternative involves initially supplying fluid to cavity **20**, halting the fluid supply while a quantity of plastic is ejected, then again supplying fluid after a main portion of plastic has been ejected. Related schemes could be undertaken wherein valve **25** is operated to allow an initial pressure buildup (held closed), followed by a pressure drop (opened), then followed by another build (closed). The various possible fluid injection schemes are available for different mold and plastic characteristics, and considerable variation on the presently disclosed processes is possible without departing from the scope of the present invention. For instance, any of the fluid injection events could be undertaken with either a gas or a liquid, for instance water. The plastic injectors, mold cavities, runners, and cylinders are all known in the art. Suitable injection pins such as Applicant's ANP series gas pin or multi-fluid pin are commercially available, as are fluid injection controllers, such as Applicant's LGC series gas-assist controller, which can adjust the pressure and timing of fluid introduced into the chambers.

It should be understood that the present description is for illustrative purposes only and should not be construed to limit the scope of the present invention in any way. Thus, those skilled in the art will appreciate that various modifications could be made to the presently disclosed embodiments without departing from the intended spirit and scope of the present invention. Other aspects, features, and advantages will be apparent upon an examination of the attached drawing figures and appended claims.

What is claimed:

1. A process for injection molding of fluid filled plastic bodies in an apparatus having a mold cavity and a separate fluid reservoir, the process comprising the steps of:

connecting a source of flowable plastic material fluidly to the mold cavity with a supply passage;

positioning at least one fluid injection pin partially within the mold cavity, the fluid injection pin being connectable to a fluid source;

injecting a quantity of flowable plastic into an interior of the mold cavity through the supply passage;

cooling part of the plastic melt along walls of the mold cavity, thereby providing an interior of flowable, plastic melt;

injecting a quantity of fluid from the fluid source into the interior of flowable, plastic melt;

selectively expelling at least a portion of the interior of flowable, plastic melt into the supply passage; and

selectively expelling at least a portion of fluent plastic from the supply passage into the reservoir.

2. The process of claim **1** further comprising the step of injecting a second quantity of fluid from said fluid source into the mold cavity.

3. The process of claim **1** further comprising the steps of injecting a plurality of discrete quantities of fluid from the fluid source into the mold cavity.

4. The process of claim **1** wherein the step of injecting a flowable plastic is characterized by injecting the flowable plastic material in a downstream direction; and

the step of injecting a quantity of fluid is characterized by injecting the gas in an upstream direction to eject a portion of the flowable plastic from the mold.

5. The method of claim **1** wherein said fluid is a compressible fluid.

6. The method of claim **1** wherein said fluid is a non-compressible fluid.

7. The method of claim **1** wherein said fluid includes compressible and non-compressible fluids.

8. A process for injection molding of plastic bodies in a molding apparatus having a mold cavity, the process comprising the steps of:

injecting a quantity of flowable plastic into the mold cavity;

injecting a quantity of pressurized compressible fluid into the interior of said flowable plastic in said cavity, increasing the pressure within said cavity;

selectively connecting the mold cavity with a reservoir after cessation of pressurized fluid injection, so that a portion of said flowable plastic flows from the mold cavity.

9. The process of claim **8** wherein said step of selectively connecting is characterized by actuating a control valve to fluidly connect the mold cavity with the reservoir.

10. The process of claim **9** wherein said portion of the interior of flowable plastic flows from the mold cavity in the direction of said injection of flowable plastic.

11. The process of claim **9** wherein said portion of the interior of flowable plastic flows from the mold cavity in an upstream direction opposite the direction of said injection of flowable plastic.

12. A process for injection molding of hollow articles in an apparatus having a mold cavity and a reservoir, the process comprising the steps of:

injecting fluent plastic into the apparatus;

injecting a pressurized compressible fluid into the fluent plastic, the fluid forming a pocket of pressurized fluid therein;

maintaining fluid pressure in the mold a predetermined duration after cessation of said fluid injection;

selectively connecting the mold cavity to the reservoir, so that a portion of the fluent plastic flows to the reservoir.

13. The process of claim **12** wherein the predetermined duration is about two seconds to about ten seconds.

14. The process of claim **12** wherein the step of selectively connecting the mold cavity to the reservoir includes actuating a control valve to fluidly connect the mold cavity therewith.

15. The process of claim **12** wherein the portion of fluent plastic flows to the reservoir in a downstream direction.

16. The process of claim **12** wherein said portion of the fluent plastic flows from the mold cavity in the direction of said injection of fluent plastic.

17. The process of claim **12** wherein said portion of the fluent plastic flows from the mold cavity in a direction opposite to the direction of said injection of fluent plastic.

18. A method for injection molding a part having at least one cavity therein, comprising the steps of;

injecting thermoplastic melt from an injection unit along a melt flow path into a cavity of an injection molding tool to partially fill the cavity;

selectively isolating said melt flow path from said cavity;

injecting a compressible fluid into the thermoplastic melt; and then

selectively connecting said melt flow path with said cavity so that a portion of said thermoplastic melt flows from said cavity.

* * * * *

US005824261A

United States Patent [19]

Berdan

[11] Patent Number: 5,824,261

[45] Date of Patent: Oct. 20, 1998

[54] MULTI-VENTING MOLDING APPARATUS

[75] Inventor: Karl Berdan, Midland, Canada

[73] Assignee: JPE, Inc., Ann Arbor, Mich.

[21] Appl. No.: 677,947

[22] Filed: Jul. 10, 1996

[51] Int. Cl.[6] B29C 45/00

[52] U.S. Cl. 264/572; 425/130

[58] Field of Search 264/572; 425/130

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5,078,949	1/1992	Strunk et al.	264/572
5,090,886	2/1992	Jaroschek	264/572
5,204,050	4/1993	Loren	264/504
5,423,667	6/1995	Jaroschek	425/130
5,484,278	1/1996	Berdan	264/572
5,612,067	3/1997	Kurihara et al.	264/572

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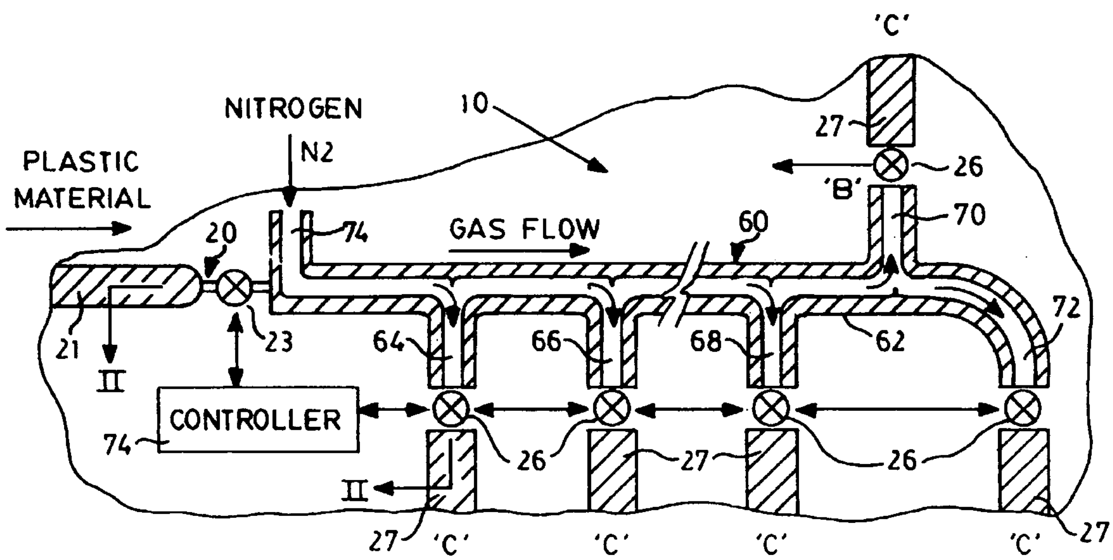
2287212	9/1995	United Kingdom	B29C 45/17

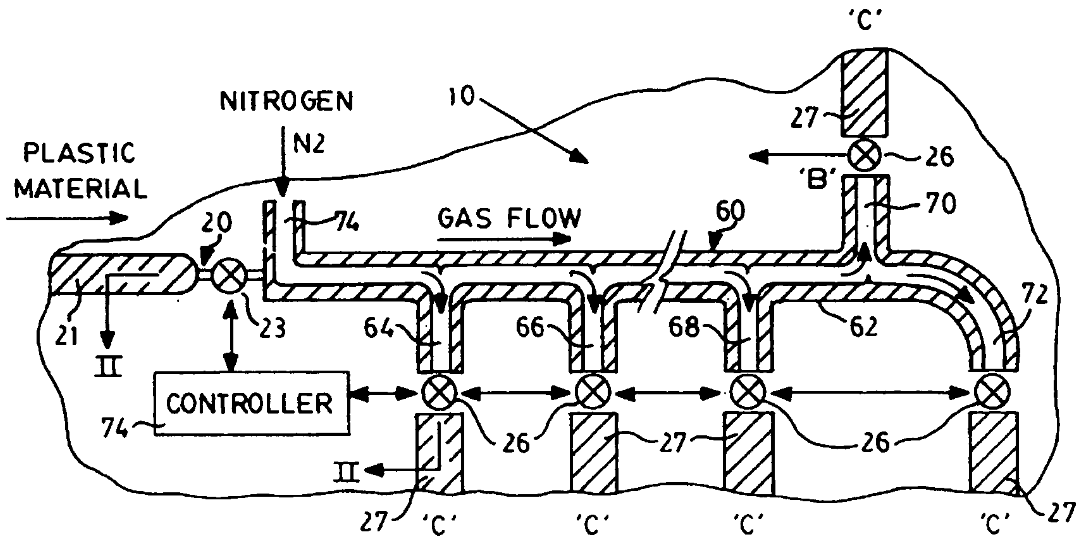
Primary Examiner—Catherine Timm
Attorney, Agent, or Firm—Ladas & Parry

[57] ABSTRACT

A multiple limbed component is molded in a gas injection mold with a corresponding number of outlets. The outlets are regulated by valves that are operated sequentially to permit progressive expulsion of the excess material in the mold cavity.

5 Claims, 2 Drawing Sheets

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27
26
'B'
70
NITROGEN
10
N2
PLASTIC
MATERIAL
74
GAS FLOW
60
20
72
21
23
64
66
68
62
II
CONTROLLER
74
26
27
26
27
II
27
'C'
'C'
'C'
'C'
27

FIG. 1

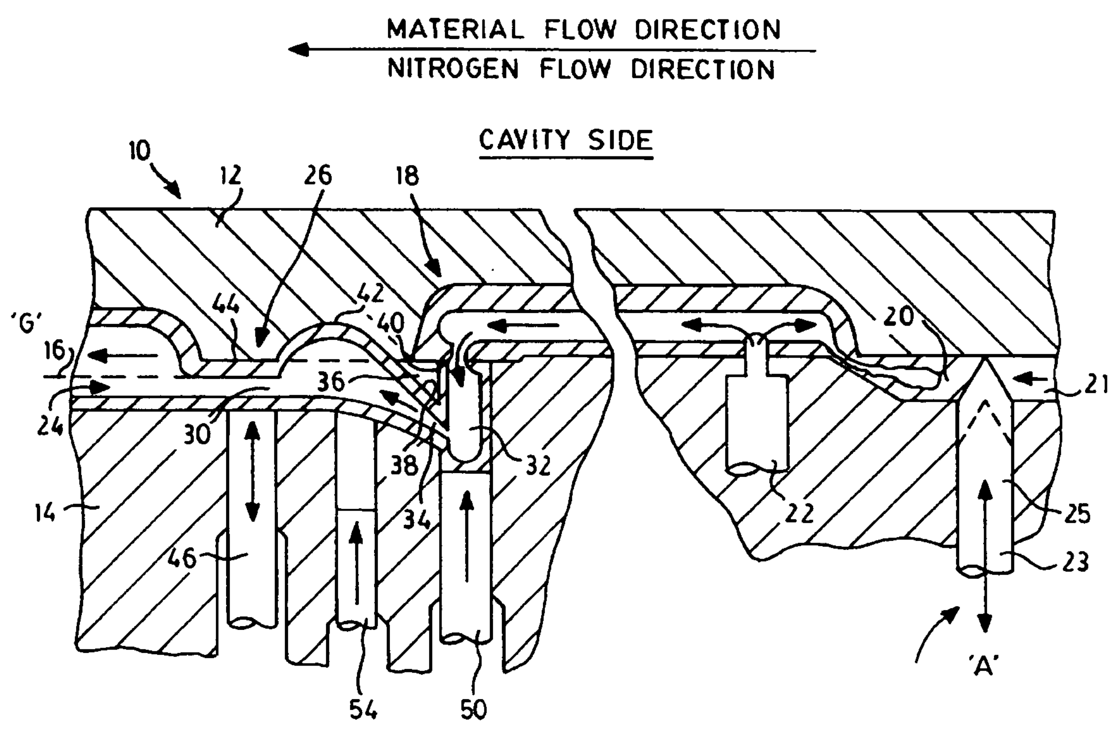
MATERIAL FLOW DIRECTION
NITROGEN FLOW DIRECTION
CAVITY SIDE
10
12
26
18
'G'
44
42
40
20
16
36
21
24
30
38
32
34
22
25
14
46
23
54
50
'A'

FIG. 2

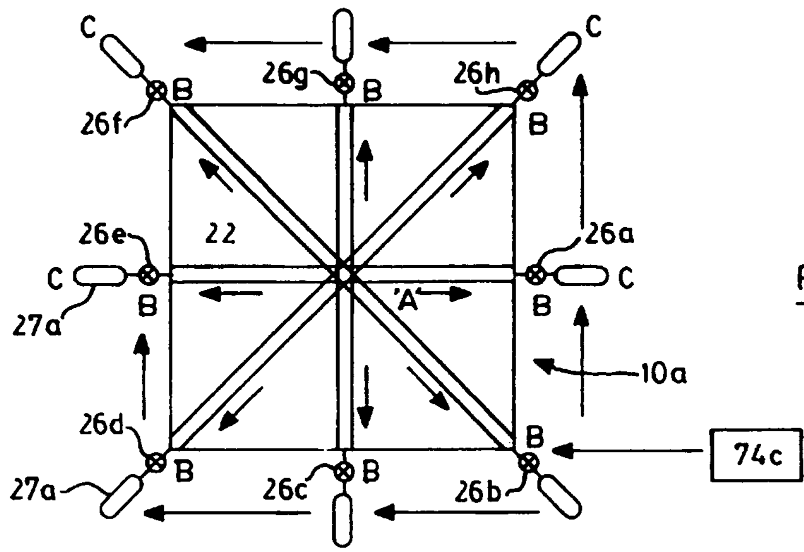

FIG. 3

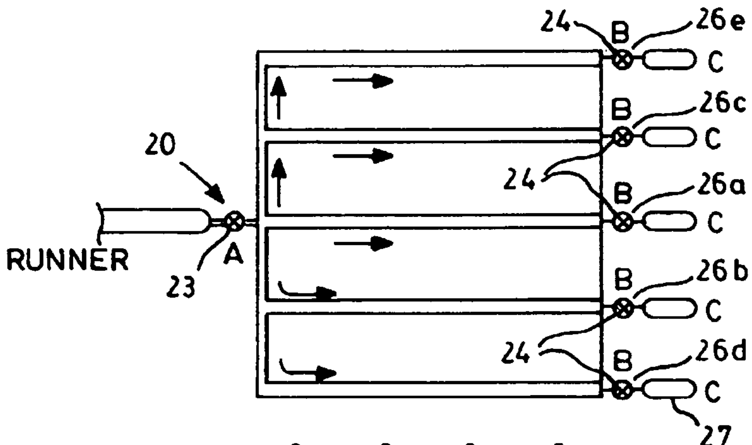

FIG. 4

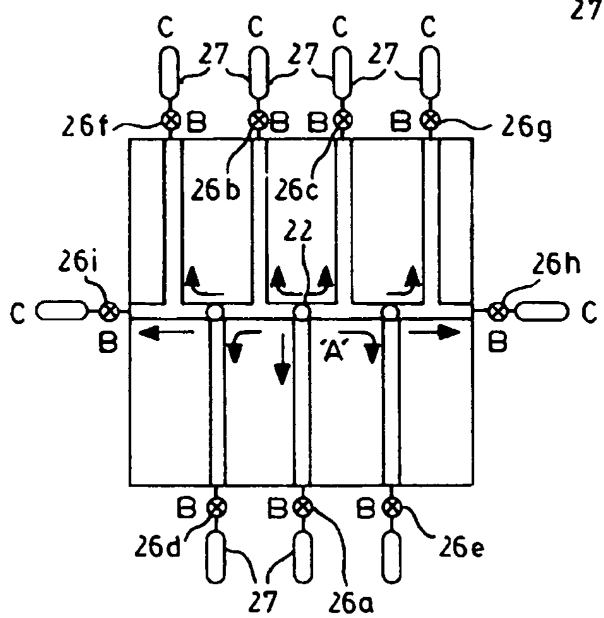

FIG. 5

MULTI-VENTING MOLDING APPARATUS

The present application relates to gas-assisted injection molding apparatus and methods of performing such molding.

Gas-assisted injection molding involves the injection of gas into a molding cavity so as to expel a portion of the molding material from the cavity. The molding material in contact with the outer walls of the cavity solidifies upon injection of the molding material into the cavity and the subsequent injection of gas therefore can remove the liquid central portion of the molding material. The result is a hollow molded article that uses less material and is lighter in weight.

To obtain high quality product from such molding processes, the egress of molding material must be carefully controlled. If insufficient material is expelled, the result will be a relatively thick-walled, possibly solid article, and if the ejection is not properly performed, the finished article may show surface deformation that renders it unsuitable for subsequent processing.

These problems are addressed in U.S. Pat. No. 5,484,278 in which provision is made for control of the venting of the cavity by means of a vent valve and subsequent quality control is facilitated by the provision of a shear that allows visual inspection of the wall thickness associated with the finished article. The use of the vent valve assembly shown in the above patent has improved the quality of the resultant product. However, it has been found that where complex articles are to be manufactured, further control of the material flow from the cavity is required.

U.S. Pat. No. 5,090,886 discloses an injection molding apparatus in which provision is made for venting the cavity into a pair of outlets which are subsequently closed by stuffers in the cavity. This arrangement, however, does not provide for control of the inlet of the cavity and does not facilitate the molding of complex components that may have multiple limbs or complex shapes.

In the molding of such articles, it is necessary to ensure that each internal cavity is properly evacuated, not only for correct functioning of the component but also to permit subsequent processing.

Frequently the components molded will be painted and subjected to secondary heating which is taken into account when designing the component. If, however, the cavity is not properly evacuated, then the component will have significant stress induced during heating due to unequal wall thickness. This results in deformation and warpage of the component and a high rate of rejection.

It is therefore an object of the present invention to provide a molding apparatus and a method of molding which obviates or mitigates the above disadvantages.

In general terms, the present invention provides a molding machine in which multiple outlets are provided from the molding cavity to permit the molding of complex articles. Each of the outlets has a control valve associated with it that may be controlled to regulate the flow of material through the outlet passage. A valve is also associated with the inlet passage and a controller controls each of the valves such that the inlet valve is closed when the outlet valves are opened and that the outlet valves can be closed during at least a portion of the period in which gas is injected into the cavity.

More particularly, the present invention provides a gas-assisted injection molding machine comprising a mold cavity, a material inlet passage to transport molding material from a source to said cavity, a plurality of outlets from said cavity to permit egress of material therefrom, an inlet valve in said inlet passage to control flow of material along said inlet passage, an outlet valve in each of said outlet passages to control flow of material along said outlet passages, a gas injector to inject pressurized gas into said cavity to expel material therefrom and a control to control operation of said valves, said control closing said inlet valve during injection of said gas to inhibit flow in said inlet passages and opening said outlet valves during at least a portion of said injection of said gas to vent said cavity.

In a further aspect, the present invention provides a gas-assisted injection molding machine wherein said vent valves are operated sequentially during injection to open said passage and said shears are operated simultaneously upon ejection of molded material from said cavity.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings, in which

FIG. **1** is a schematic section of a cavity for a molded article;

FIG. **2** is a section on the line **2**—**2** of FIG. **1**;

FIG. **3** is an alternative embodiment of a mold cavity;

FIG. **4** is a further embodiment of a mold cavity; and

FIG. **5** is a still further embodiment of a mold cavity utilizing the components of FIG. **2**.

Referring therefore to FIGS. **1** and **2**, a gas-assisted injection molding apparatus generically identified as **10** has a cavity side **12** and a core side **14** that abut along the common plane indicated at **16**. A cavity **18** is formed in the cavity side **12** and, together with the core side **14**, defines the exterior surface of an article to be molded. As can be seen from FIG. **1**, the article to be molded in the embodiment illustrated is a multiple outlet tubular manifold indicated at **60** having a main duct **62** and branches **64**,**66**,**68**,**70** and **72**. An inlet **74** communicates with the main duct **62**. The article **60** is to be molded with a relatively thin peripheral wall and a hollow interior to allow passage of fluids from the inlet **74** to one of the branches **64**–**72**. It will be understood that the article **60** is by way of illustration only and, as will be described more fully below with reference to FIGS. **3**–**5**, a variety of different shaped articles may be utilized with appropriate configuration of the cavity **18**.

Referring again to FIG. **2**, molding material is supplied through an inlet passageway **20** that extends between the supply of molding material **21** and the cavity **18**. An inlet control valve **23** is positioned in the passageway **20** and consists of a retractable pin **25** that may be moved to a position in which the inlet passageway **20** is sealed.

A gas injection nozzle **22** is positioned in the core side **14** to project into the cavity **18** and supply gas under pressure to the interior of the cavity **18**.

Molding material is expelled from the cavity **18** through one of a number of outlet passages **24**. An outlet passageway **24** is associated with each of the branches **64**–**70**.

Each of the outlet passages **24** includes a vent valve assembly **26** that controls the flow of molding material from the cavity **18** through the passage **24** and to a respective reservoir **27**.

As is well known in the art, the cavity side **12** and core side **14** are movable relative to one another between a closed position as shown in FIG. **2** in which the cavity defines the outer surface of the article to be molded, and an open position in which the cavity side and core side are separated to allow the molded article to be removed. The mounting of the mold to permit this relative motion is well known in the art and need not be described further. Similarly, the provision of molding material to the inlet passageway **20** and the provision of the gas to the nozzle **22** is known in the art and will not be described further.

The form of the passageway **24** in which the vent valve assembly **26** is located includes a horizontal leg **30** and a vertical leg **32** that intersect at a throat **34**. The legs **30**,**32** are separated by an anvil **36** that is defined by a pair of convergent surfaces that intersect at an apex having an acute included angle. The vertical leg **32** extends from the cavity **18** and is of uniform circular cross-section. The horizontal leg **30** is of progressively increasing cross-section as it extends from the throat **34** and has a smoothly curved dome wall **42** extending from the surface **38** across the common plane **16**. The domed wall **42** terminates at a planar abutment surface **44** that extends to the reservoir **27**.

The vent valve **26** includes a valve member **46** to regulate flow through the passageway **24**, a shearing pin **50** to sever material in the passageway **24**, and an ejector pin **54** to eject material from the passageway **28**. Valve member **46** is slidably mounted in a bore **48** provided in the core member **14** opposite the abutment surface **44**. The valve member **46** is movable under the control of a controller **74** by air or hydraulic fluid and is effective to prevent flow through the passageway **24**.

Shearing pin **50** is slidably mounted in a bore **52** provided with an extension of the vertical leg **32**. The shearing pin **50** is slidable across the throat **34** and into the vertical leg **32** along the surface **40**.

Ejector pin **54** is likewise slidably mounted in a bore **56** opposite the dome wall **52** and is slidable along the bore **56** to engage and eject material in the passageway **24**. The valve member **46**, shearing pin **50** and ejector pin **54** are operated by control signals from the controller **74** and may be operated by air hydraulic electrical or mechanical cam actuation and interlocked with the operation of the mold.

The controller **74** is operable to operate the valve members **46** of each of the vent valve assemblies **26** independently and also control operation of the inlet valve **23** in the inlet passageway **20**.

In operation, the cavity side **12** and core side **14** are moved to a closed position to define the cavity **18**. Material is introduced in the molten state through the inlet passageway **20** to fill the cavity **18**. In this condition, the controller **74** maintains the vent valve assemblies **26** closed and the inlet valve **23** open. Once the cavity **18** is full, the inlet valve **23** is closed by controller **74** and a gas under pressure is introduced through the nozzle **22**. At the same time, a first outlet valve **26** that is closest to the point of injection of the gas is opened and the material in the cavity is expelled through the associated passageway **24** to the overflow reservoir **27**. An outer wall of molding material is left within the cavity following the application of gas between the injection point and the outlet. The overflow reservoir is sized to correspond to the volume of material to be expelled through the outlet with which it is associated. Accordingly, after expulsion of the material, a further vent valve **26** is opened in the outlet which is the next closest to the point of injection and material is further expelled through that outlet. The vent valve assemblies **26** are operated in sequence from the closest to the furthest from the point of injection so that material is progressively expelled from the interior of the article. The sequential opening of the valves allows close control over the flow of material, ensuring that the material is expelled in a controlled progressive manner. Once all the outlets have been opened and the material expelled, the mold is opened by separation of the cavity side and core side along the common plane **16**. The molded article remains located on the core side by virtue of its connection with material in the passageways **24**. Once the mold is opened, the shearing pin is advanced along the bore **52** and moves across the throat **34**. The shearing pin **50** engages material deposited in the vertical leg **32** and forces it against the anvil **36**. The convergent surfaces **38**,**40** enhance the shearing action of the pin **50** to sever the material in the passageway.

As the shearing pin **50** advances, it operates in conjunction with the additional ejection pins (not shown) to eject the molded article. At the same time, the ejector pin **54** is advanced along the bore **56** to engage the material in the passageway between the valve member and throat. Because the dome wall **42** and outlet passage **24** straddle the separation plane **16**, the ejector pin **50** pushes the waste material from the mold. The mold may then be prepared and closed for subsequent molding operation.

The shearing action of the pin severs the material at the throat **34** so that a cross-section of the material may be viewed after ejection by the pin **54**. Each of the cross-sections will indicate whether the waste material is voided at its associated branch giving a visual indication as to whether or not the gas has been effective to purge the material from the interior of the article. This preliminary check is a good indication as to the quality of the finished article.

The walls of horizontal leg **30** and of the passageway **28** adjacent the throat **34** diverges at an included angle in the order of 20° to facilitate removal of the waste material. The included angle between the surfaces **38** and **40** is preferably in the order of 60°, with the axis of the vertical leg being normal to the longitudinal axis of the cavity **18**. To facilitate flow of material through the passageway **24**, it is preferred that the shearing pin is retracted beyond the projection of the horizontal leg past the throat **34** as indicated.

In the above example, the overflow reservoirs **17** are sized so as to be filled once the material has been expelled. This maintains the pressure within the interior of the cavity **18** and therefore provides for expulsion of subsequent portions of the article together with an overall pressurization of the cavity once the material is expelled that promotes good surface finish on the exterior of the article.

In an alternative mode of operation, the controller **74** may be utilized to close the valve member **46** against the abutment surface **44** after the requisite material has been expelled but before the subsequent valve assembly **26** is opened. Accordingly, the valves **26** are sequentially opened then closed in accordance with their distance from the point of injection to maintain the pressurization of the cavity **18**, both during expulsion of the material and subsequent thereto.

During the expulsion of the material, the inlet valve is maintained closed so that gas is not able to pass into the source of the material.

By sequential operation of the valves and by control of the passage of gas through the cavity **18**, an improved molding is obtained even where complex shapes are to be molded.

As noted above, the article shown in FIG. **1** is merely exemplary and alternative configurations of mold may be utilized to achieve similar benefits.

In the example shown schematically in FIG. **3**, a plurality of elongate tubular articles are prepared in a common mold **10**. The injector **22** is located centrally within the mold with outlet passages **24** and respective valves **26** disposed about the periphery of the mold. An inlet **23** is also located centrally opposite the injector **22** but is not shown for clarity. Each outlet has an overflow reservoir ***27a*** associated with it. The controller ***74a*** sequences the valve so that those in the midpoint of each side, i.e. those indicated ***26a***, ***26c***, ***26e***, ***26g***, are opened initially and that the valves ***26b***, ***26d***, ***26f***, ***26h*** are opened subsequently. In this manner, a controlled expulsion of molding material is accomplished.

In the arrangement shown in FIG. **4**, a plurality of parallel elongate molded articles is obtained with the inlet passage **20** located at one edge of the mold and the outlet passages **24** located at the opposite edge. In this arrangement, the controller **74** initially opens the central vent valve indicated at **26***a* followed by the vent valves **26***b*, **26***c* and finally the vent valves **26***d*, **26***e*. Again, a progressive expulsion of material is obtained from the molded article.

In the arrangement shown in FIG. **5**, the inlet passage **20** is centrally located and the outlet passages disposed on the periphery of the mold. Again, the vent valves **26** are operated sequentially starting with the valve closest to the inlet passage **20**, so that valve **26***a* is initially opened followed by the valves **26***b* and **26***c*, then the valves **26***d* and **26***e*, followed by the valves **26***f* and **26***f*, and finally the valves **26***h* and **26***i*.

It will be seen, therefore, that by providing multiple outlets and by sequencing the operation of the valves controlling those outlets, it is possible to mold complex articles while retaining control over the quality of the finished article.

I claim:

1. A method of injection molding an article in a mold cavity having an inlet and plurality of outlets comprising the steps of injecting moldable material into said cavity through the inlet, closing said inlet to inhibit movement of material therethrough, injecting gas under pressure into said cavity to expel a portion of said moldable material therefrom through said outlets, closing said outlets during injection of gas into said cavity to pressurize said cavity and opening said outlets, one at a different time than another to permit expulsion of said material through each of said outlets at varying times so that said moldable material is expelled in a controlled progressive manner, and ejecting said article from said cavity.

2. A method according to claim **1** wherein said outlets are opened sequentially.

3. A method according to claim **2** wherein those outlets closet to the point of injection of said gas into the mold are opened before other outlets.

4. A method according to claim **3** wherein an open outlet is closed prior to opening of said outlets.

5. The method according to claim **1**, wherein the plurality outlets are sequentially opened then closed in accordance with their distance from the point of injection of the gas into the cavity in order to maintain pressurization of the cavity during expulsion of the moldable and subsequent thereto.

* * * * *

US005639417A

United States Patent [19]

Kaneishi et al.

[11] **Patent Number: 5,639,417**

[45] **Date of Patent: Jun. 17, 1997**

[54] **MOLD APPARATUS FOR PROCESS FOR INJECTION MOLDING**

[75] Inventors: **Akimasa Kaneishi; Sinji Kiboshi; Isamu Mio**, all of Hiratsuka, Japan

[73] Assignee: **Mitsubishi Gas Chemical Company, Inc.**, Tokyo, Japan

[21] Appl. No.: **463,268**

[22] Filed: **Jun. 5, 1995**

[30] **Foreign Application Priority Data**

Jul. 15, 1994 [JP] Japan 6-164334
Mar. 31, 1995 [JP] Japan 7-099715

[51] **Int. Cl.**^{6} **B29C 45/00**

[52] **U.S. Cl.** **264/572**; 425/130

[58] **Field of Search** 264/573; 425/130

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5-84764	4/1993	Japan	264/572
92/07697	5/1992	WIPO	264/572

Primary Examiner—Catherine Timm
Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

[57] **ABSTRACT**

A process for the production of a molded article having a hollow structure, using an injection molding machine equipped with a mold apparatus having a mold provided with a cavity, said process comprising the steps of

(a) positioning a plug in its forward end position in the cavity with a plug-moving means before a molten resin is injected,

(b) moving the plug toward its backward end position nearly in parallel with a flow-axis direction of the molten resin, with the plug-moving means or under a pressure of the injected molten resin, after the injection of the molten resin is initiated,

(c) introducing a pressurized fluid into the molten resin in the cavity through a pressurized fluid introducing portion while the plug is moving, and

(d) moving the plug up to its backward end position nearly in parallel with the flow-axis direction of the molten resin with the plug-moving means or under the pressure of the molten resin and/or the pressurized fluid introduced into the molten resin, and then, cooling and solidifying the molten resin in the cavity to form a hollow structure in the resin.

24 Claims, 33 Drawing Sheets

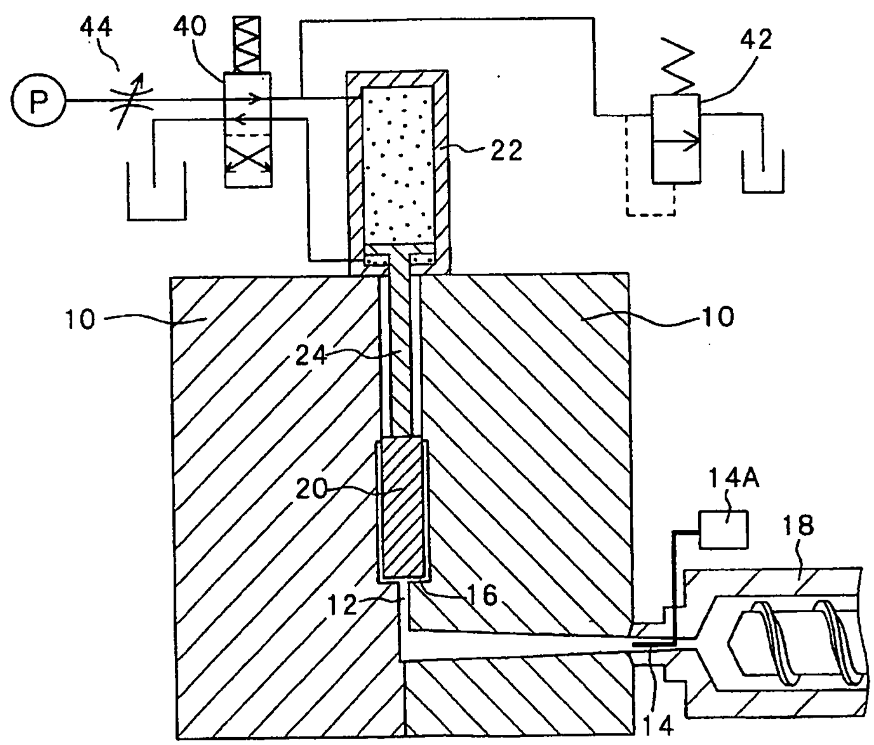


Fig. 1A

INJECTION OF MOLTEN RESIN
INTRODUCTION OF PRESSURIZED FLUID
MOVEMENT OF PLUG

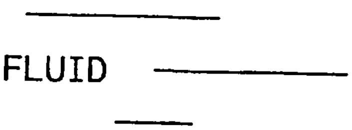


Fig. 1B

INJECTION OF MOLTEN RESIN
INTRODUCTION OF PRESSURIZED FLUID
MOVEMENT OF PLUG

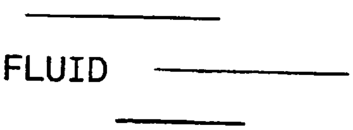


Fig. 1C

INJECTION OF MOLTEN RESIN
INTRODUCTION OF PRESSURIZED FLUID
MOVEMENT OF PLUG

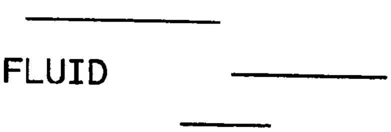


Fig. 1D

INJECTION OF MOLTEN RESIN
INTRODUCTION OF PRESSURIZED FLUID
MOVEMENT OF PLUG

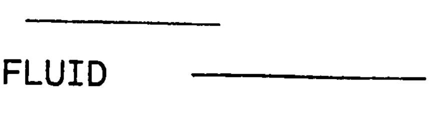


Fig. 1E

INJECTION OF MOLTEN RESIN
INTRODUCTION OF PRESSURIZED FLUID
MOVEMENT OF PLUG

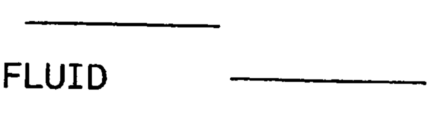


Fig. 1F

INJECTION OF MOLTEN RESIN
INTRODUCTION OF PRESSURIZED FLUID
MOVEMENT OF PLUG

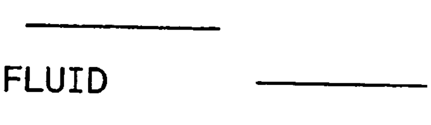


Fig. 2A

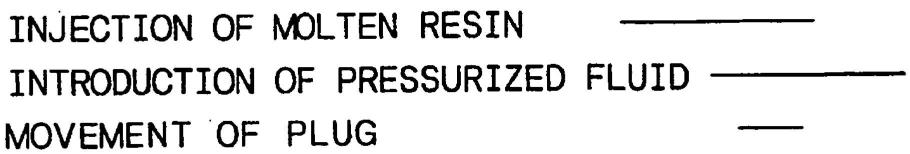


Fig. 2B

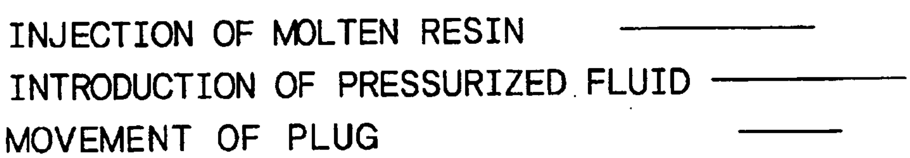


Fig. 2C

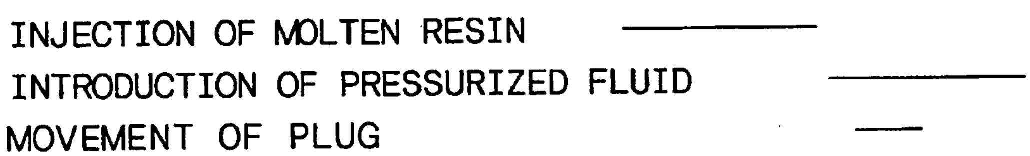
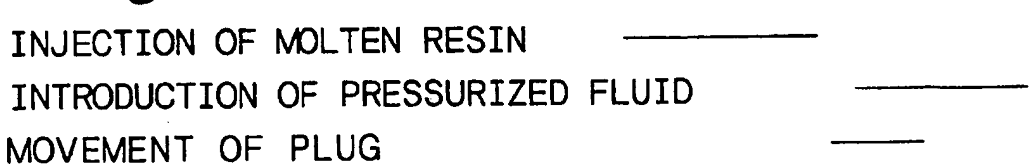


Fig. 2D



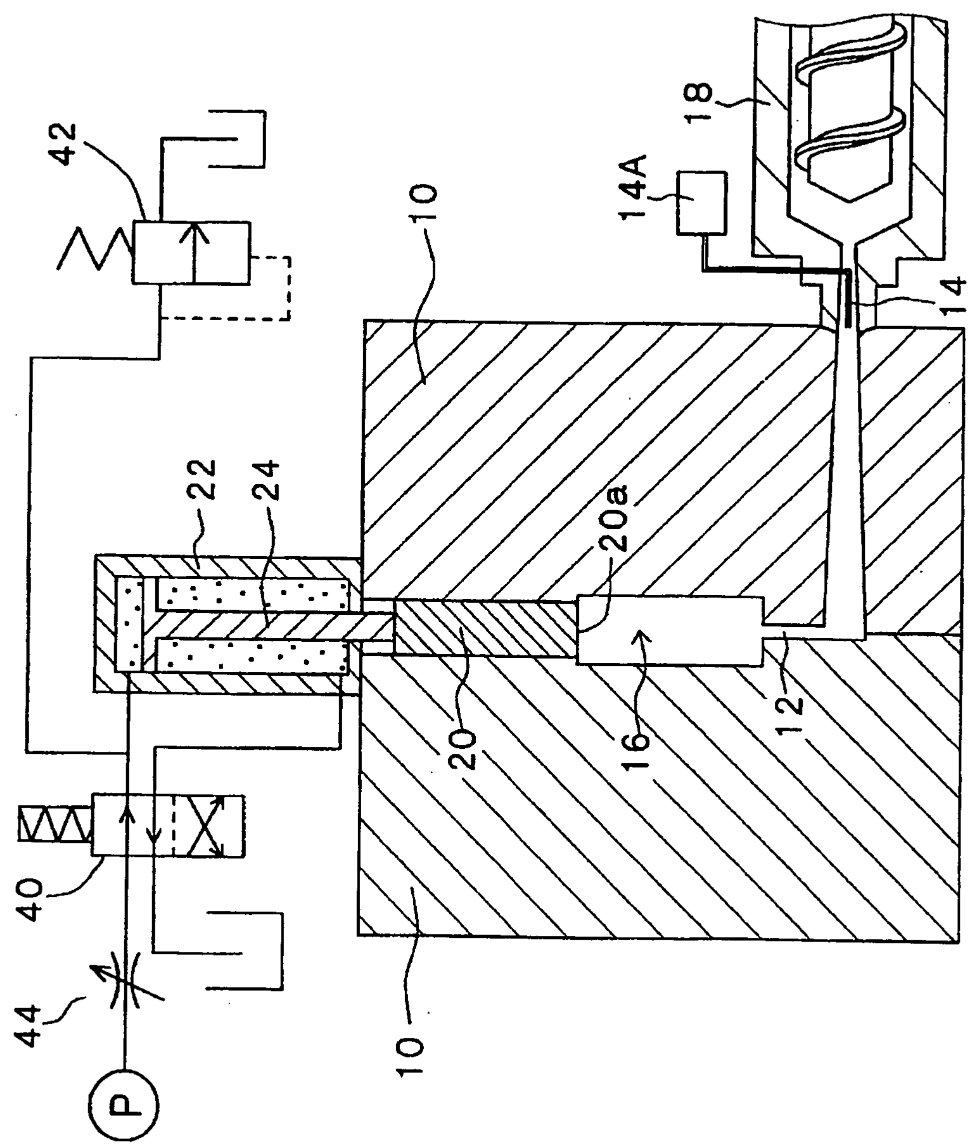


Fig. 3

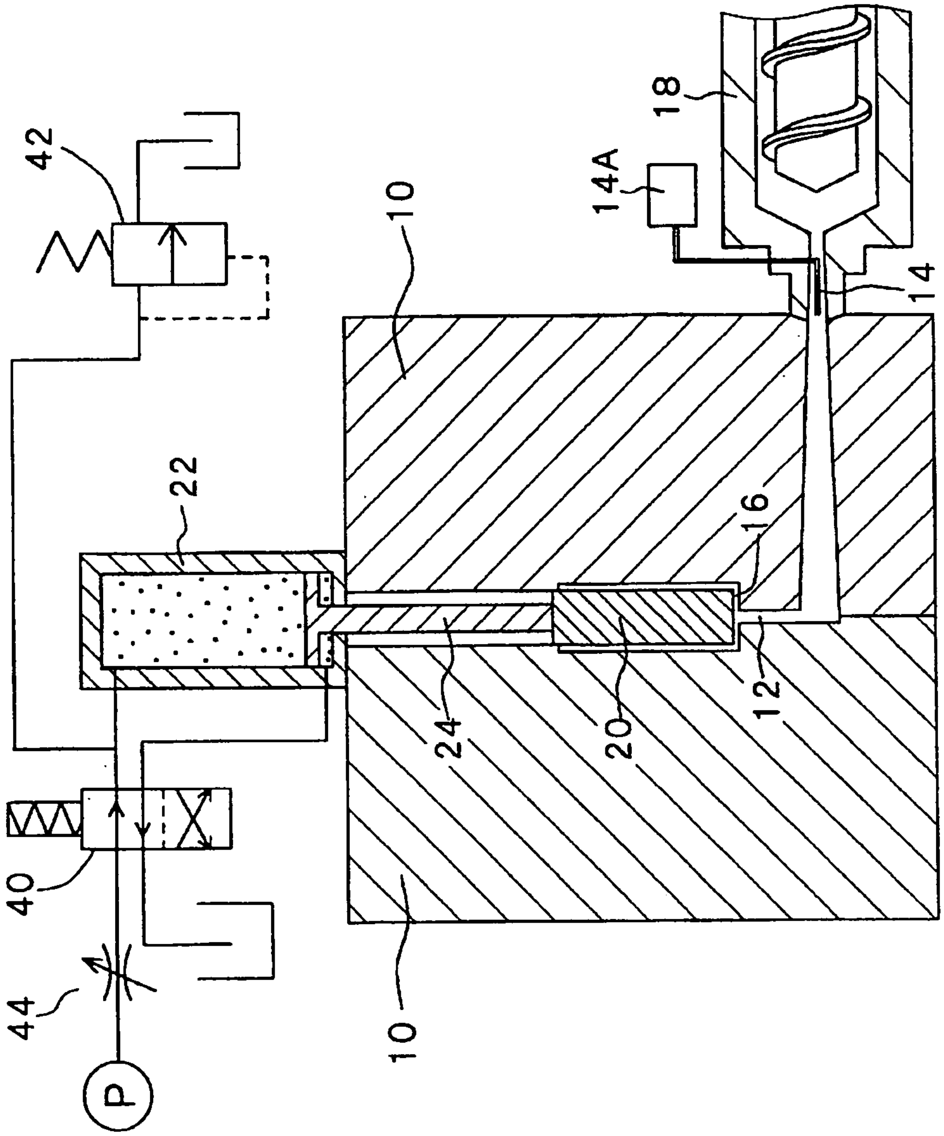


Fig. 4

Fig. 5

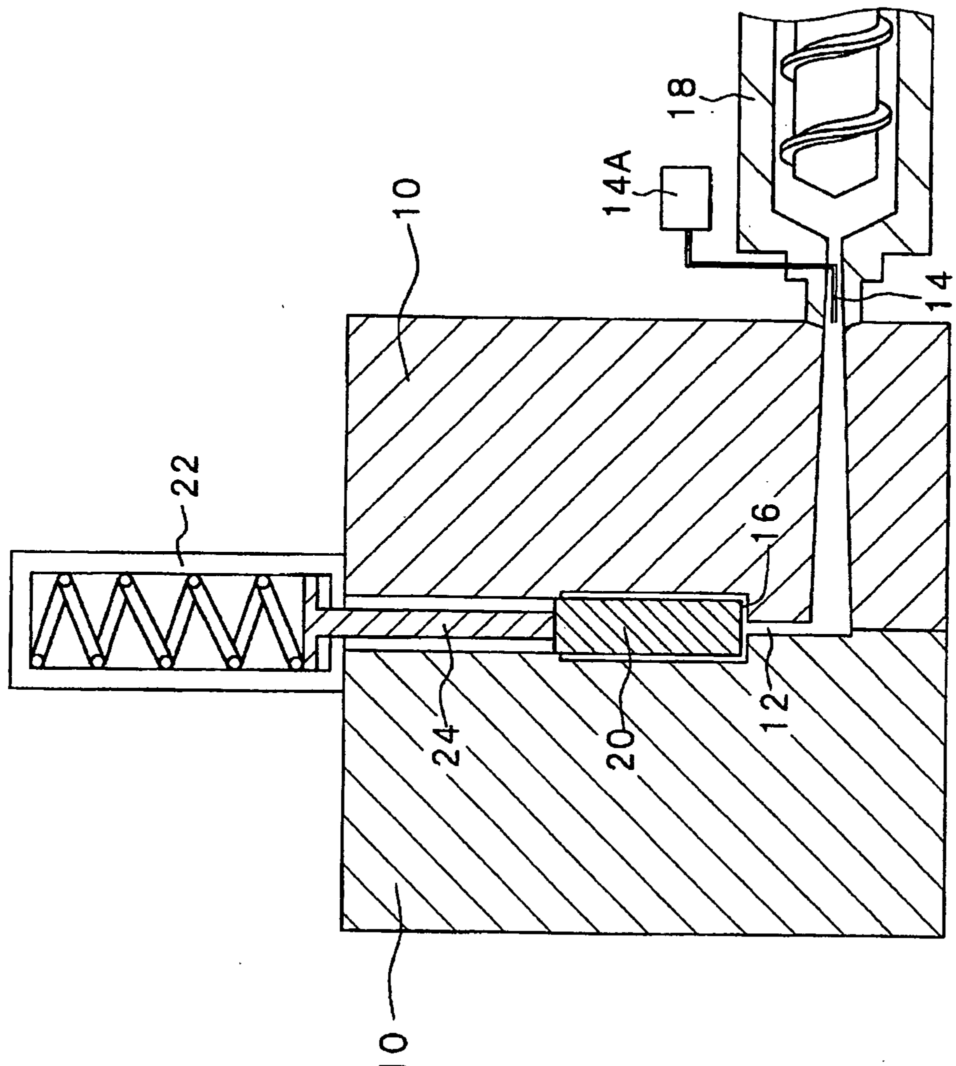


Fig. 6

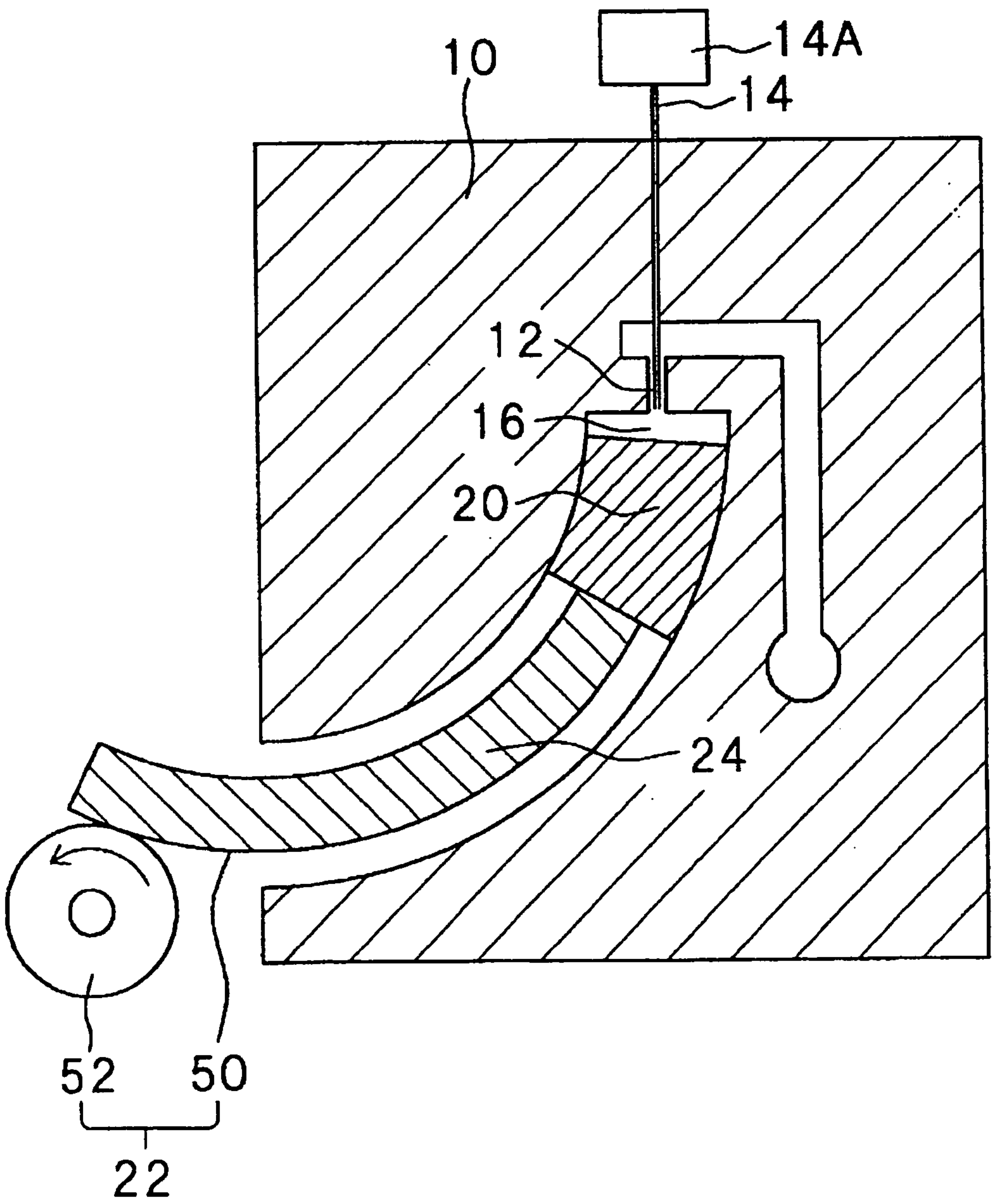


Fig. 7

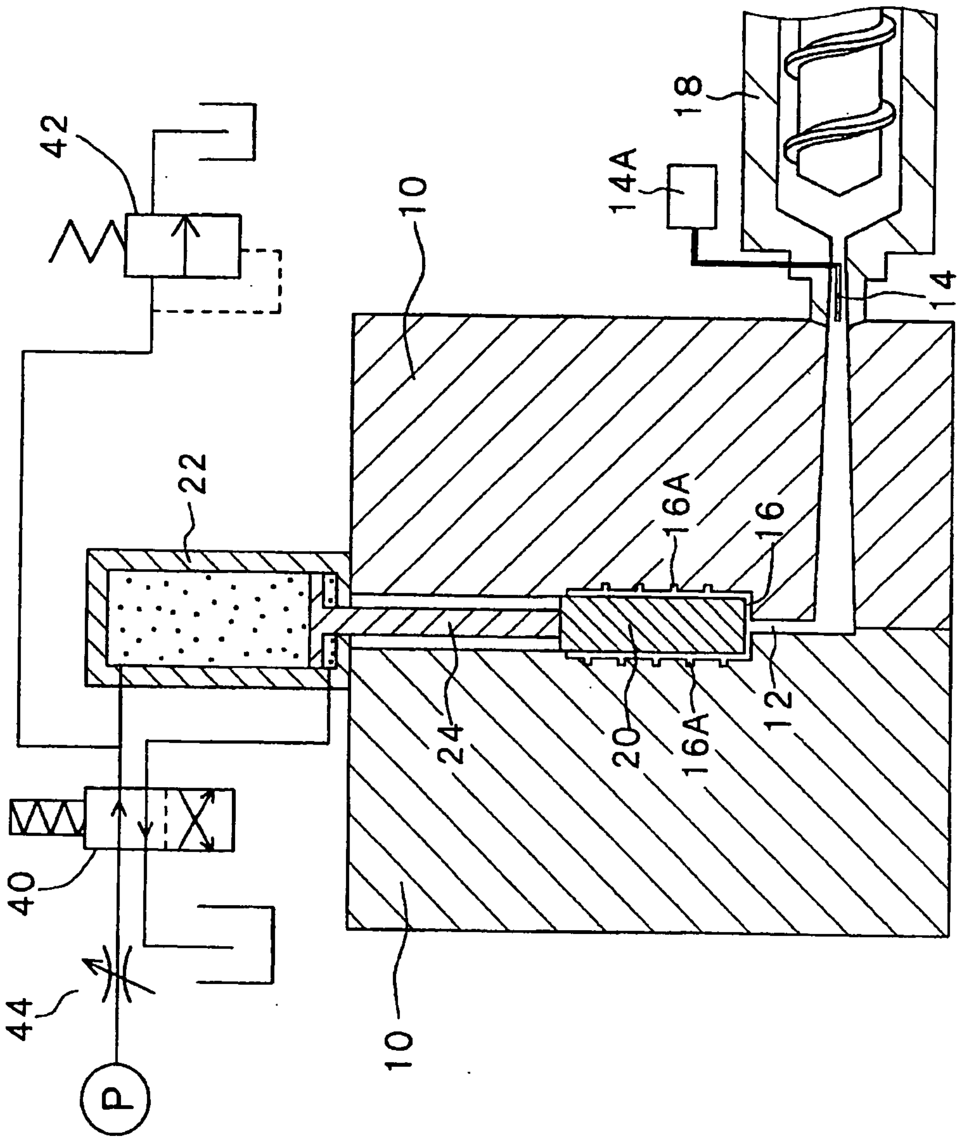
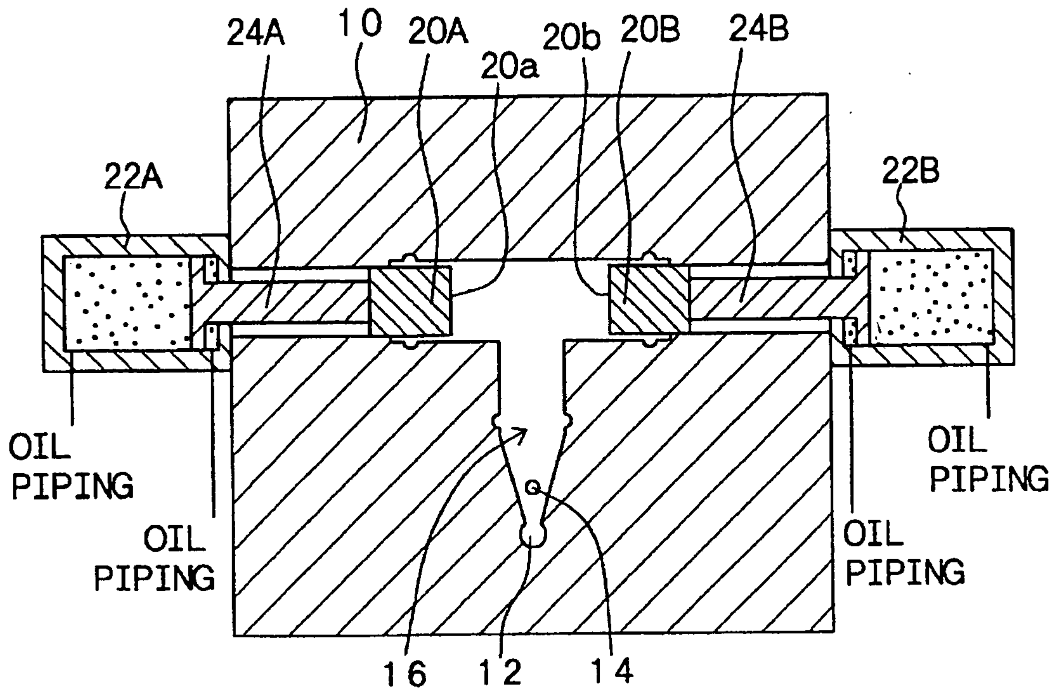


Fig. 8A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16
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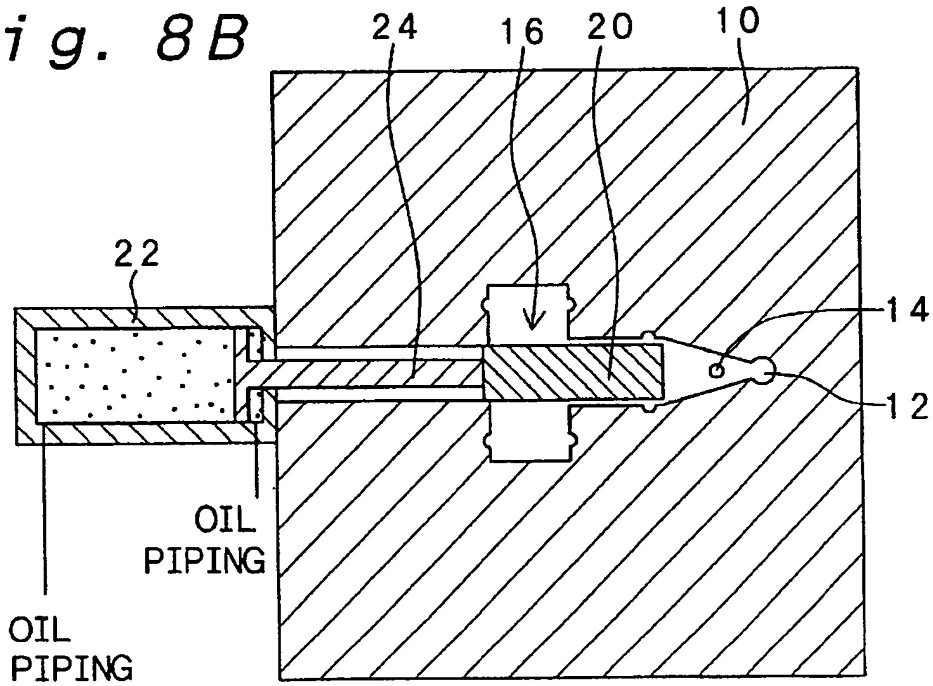
Fig. 8B


24
16
20
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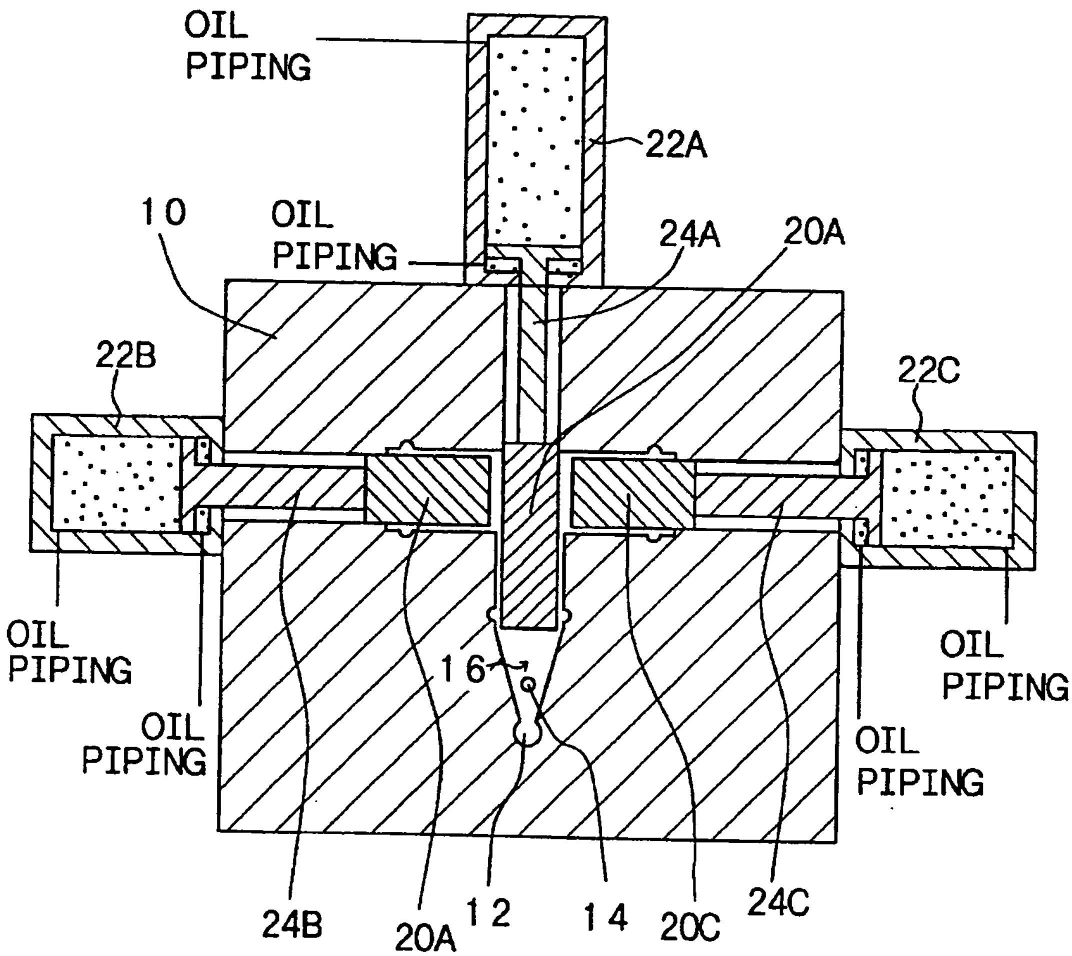
OIL PIPING

Fig. 9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PIPING
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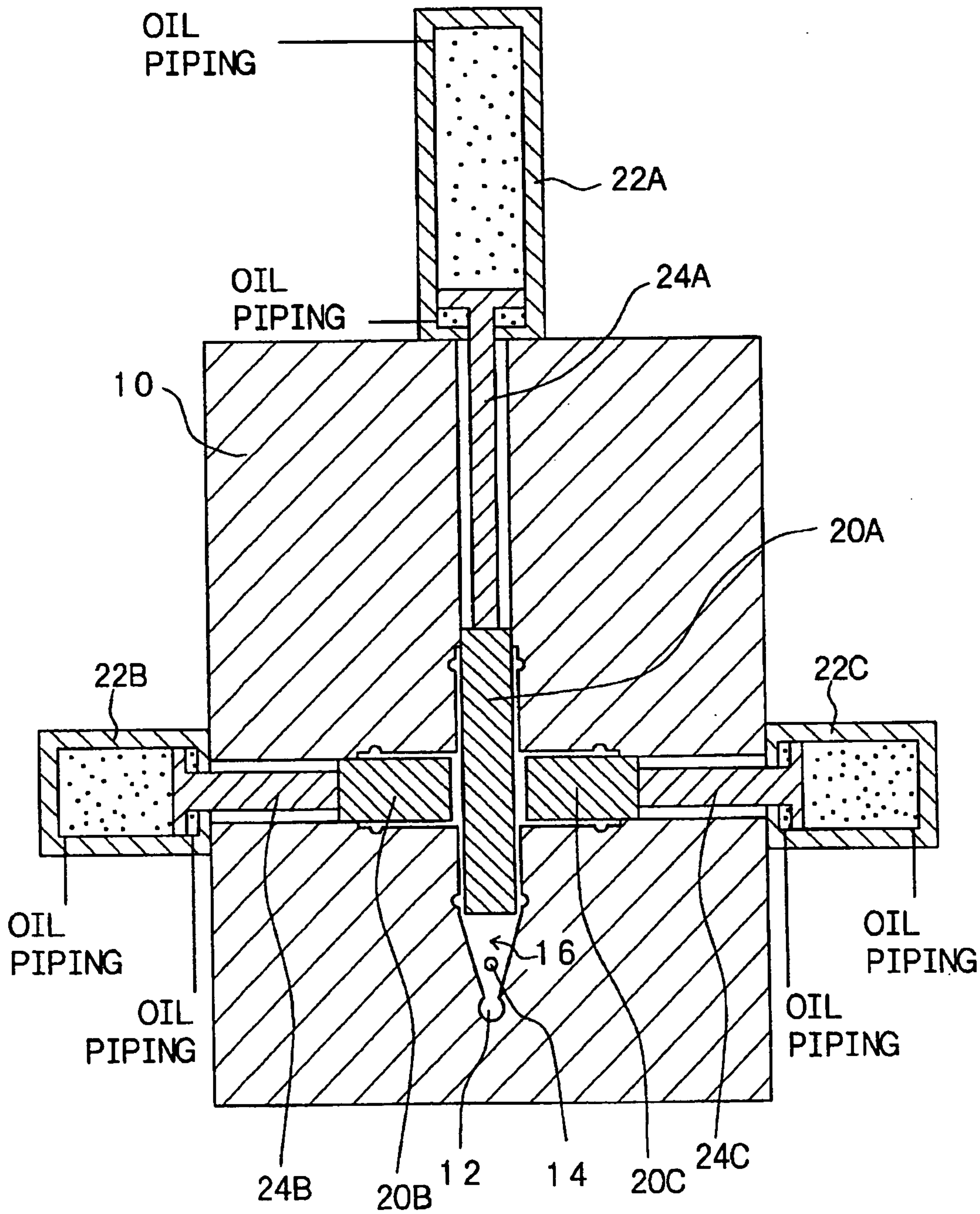
10
OIL
PIPING
24A
20A
22B
22C
OIL
PIPING
16
OIL
PIPING
OIL
PIPING
OIL
PIPING
24B
20A
12
14
20C
24C

Fig. 10


OIL
PIPING
22A
OIL
PIPING
24A
10
20A
22B
22C
OIL
PIPING
16
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OIL
PIPING
OIL
PIPING
24B
20B
12
14
20C
24C

Fig. 11

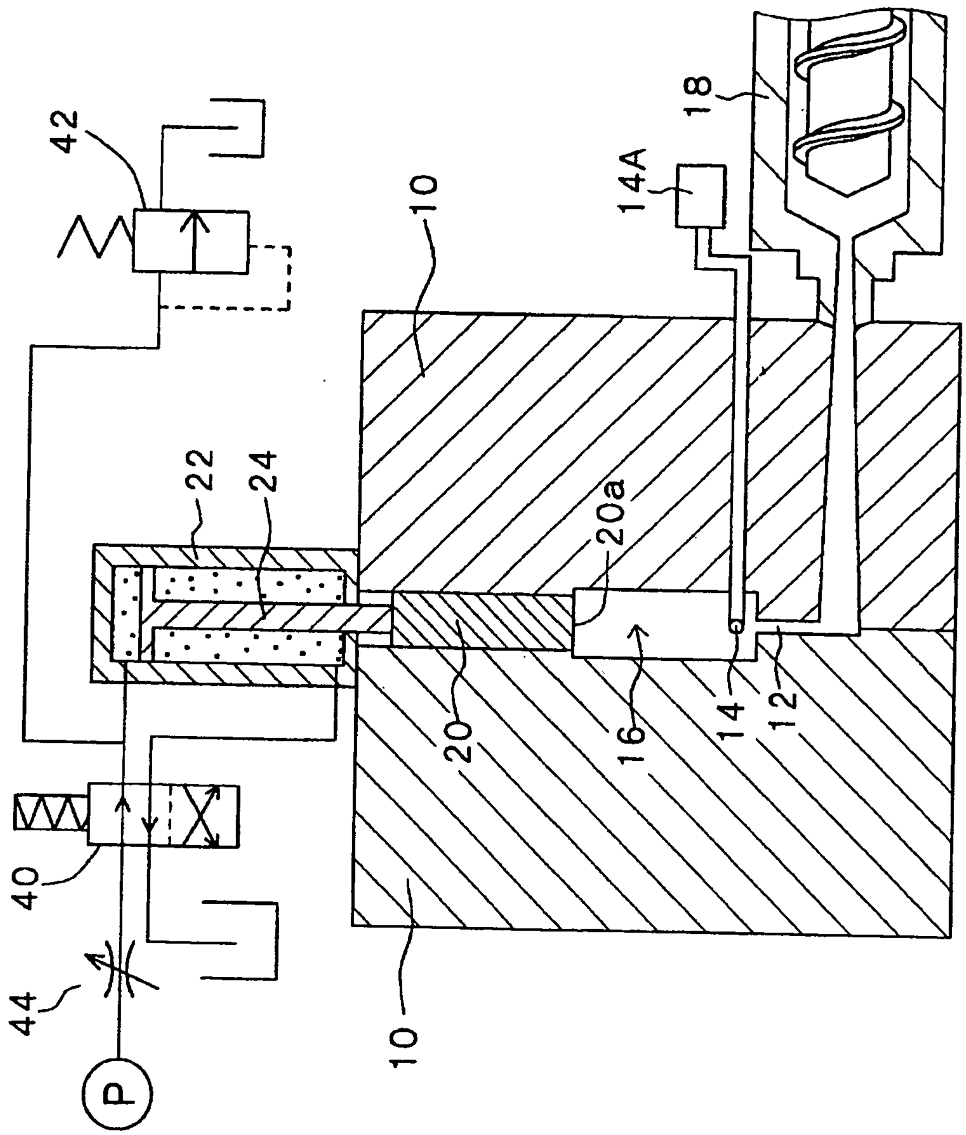
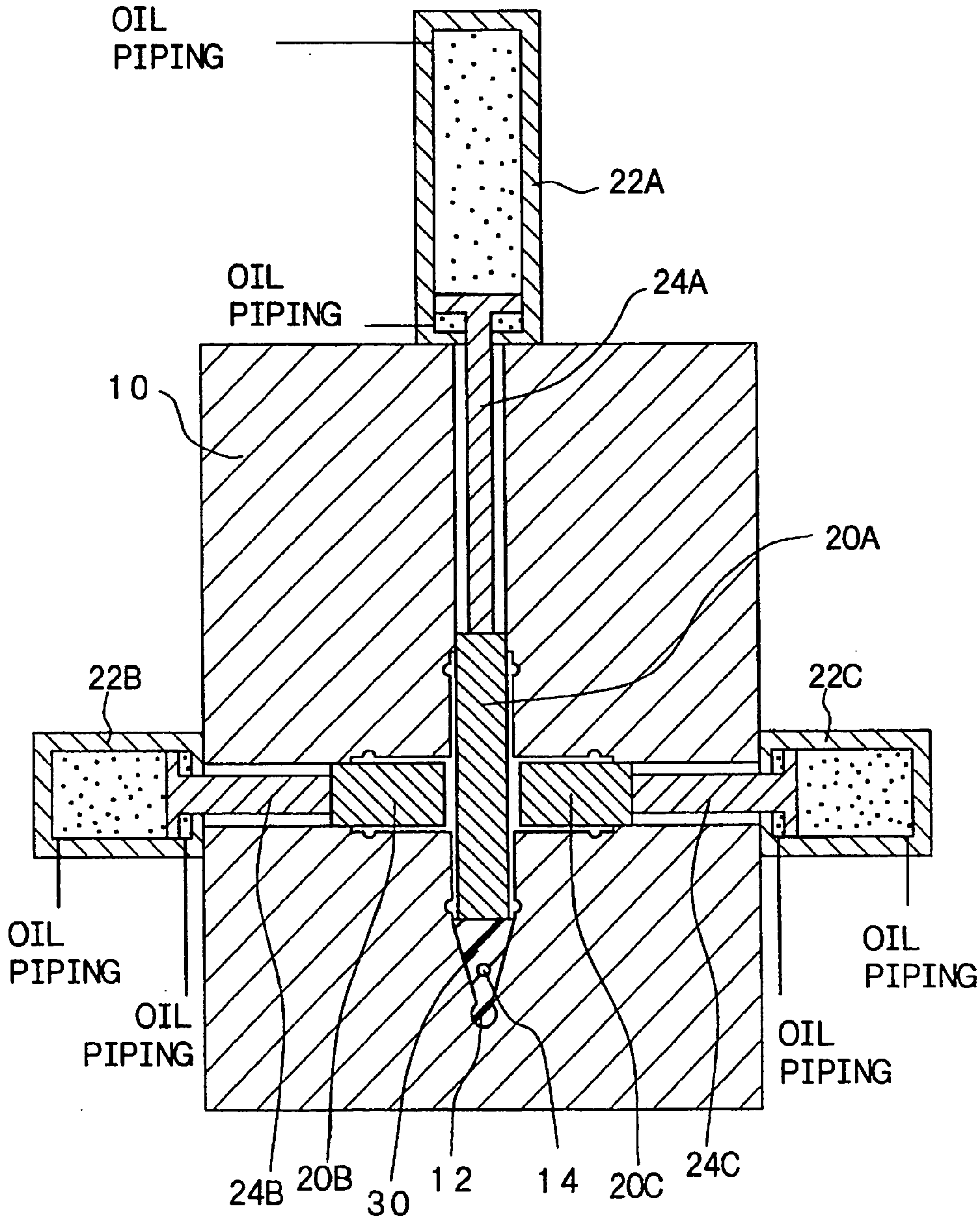


Fig. 12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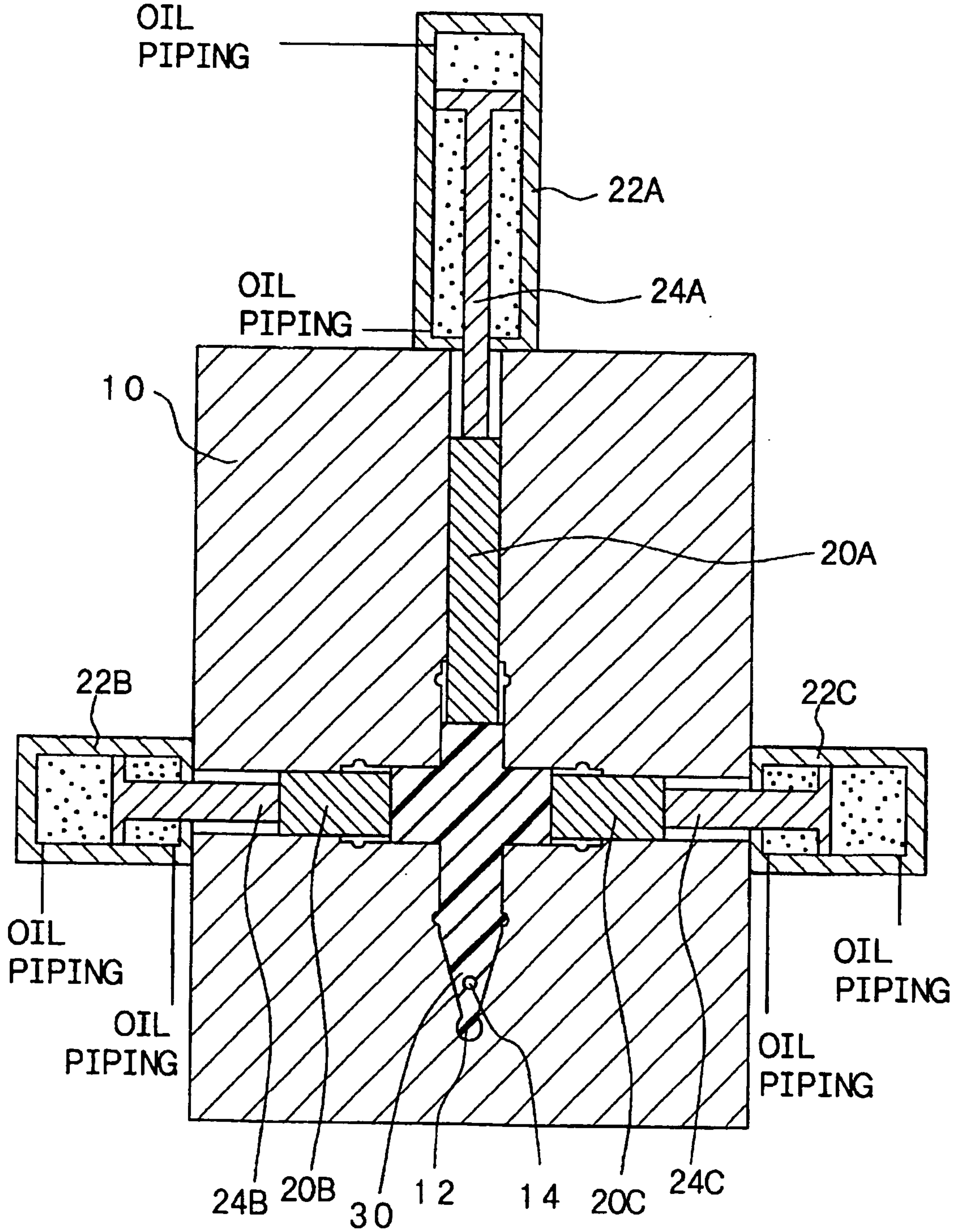
22A
OIL PIPING
24A
10
20A
22B
22C
OIL PIPING
OIL PIPING
OIL PIPING
OIL PIPING
24B
20B
30
12
14
20C
24C

Fig. 13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PIPING
22A
OIL
PIPING
24A
10
20A
22B
22C
OIL
PIPING
OIL
PIPING
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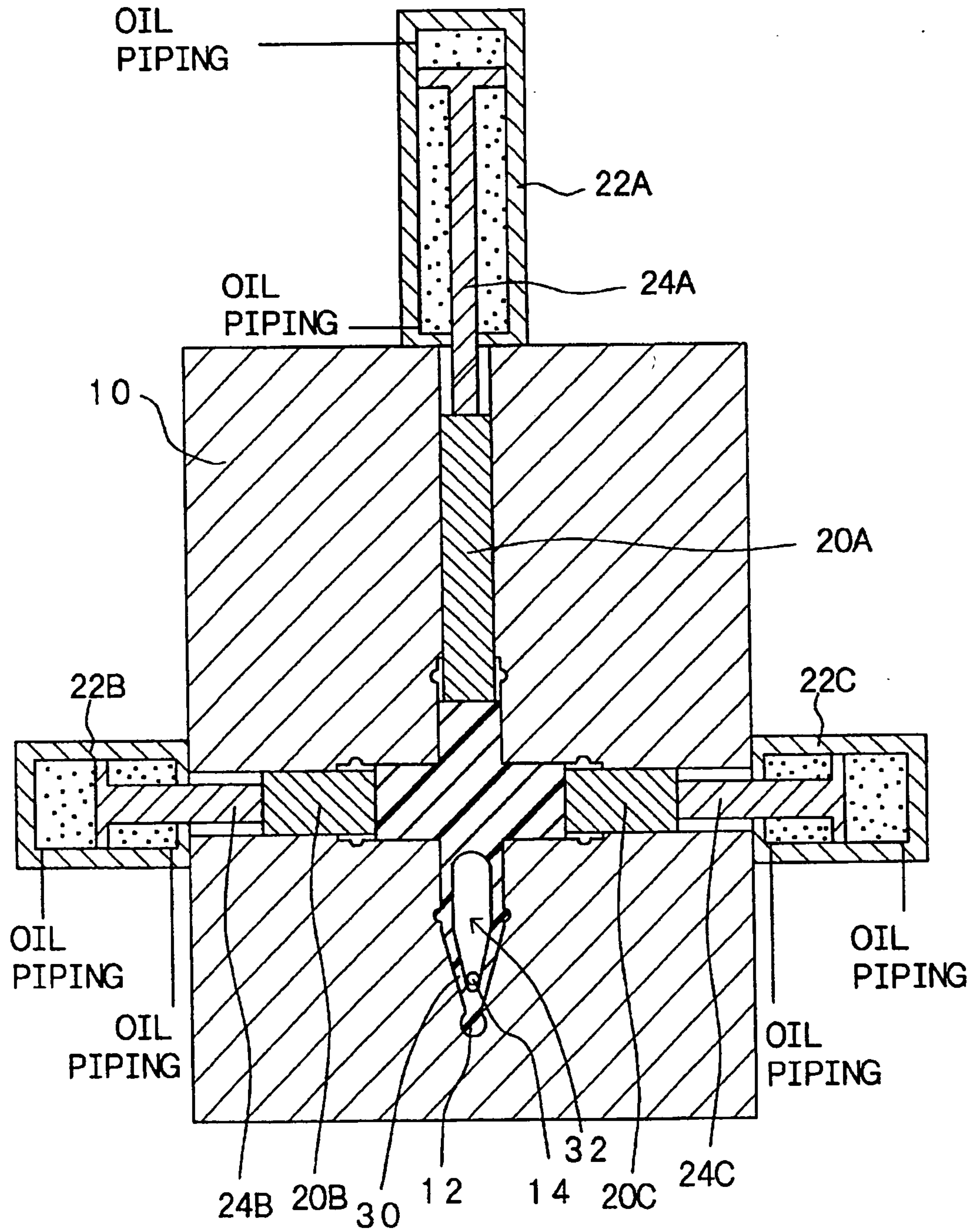
24B
20B
30
12
14
20C
24C

Fig. 14


OIL PIPING
22A
24A
OIL PIPING
10
20A
22B
22C
OIL PIPING
OIL PIPING
OIL PIPING
OIL PIPING
OIL PIPING
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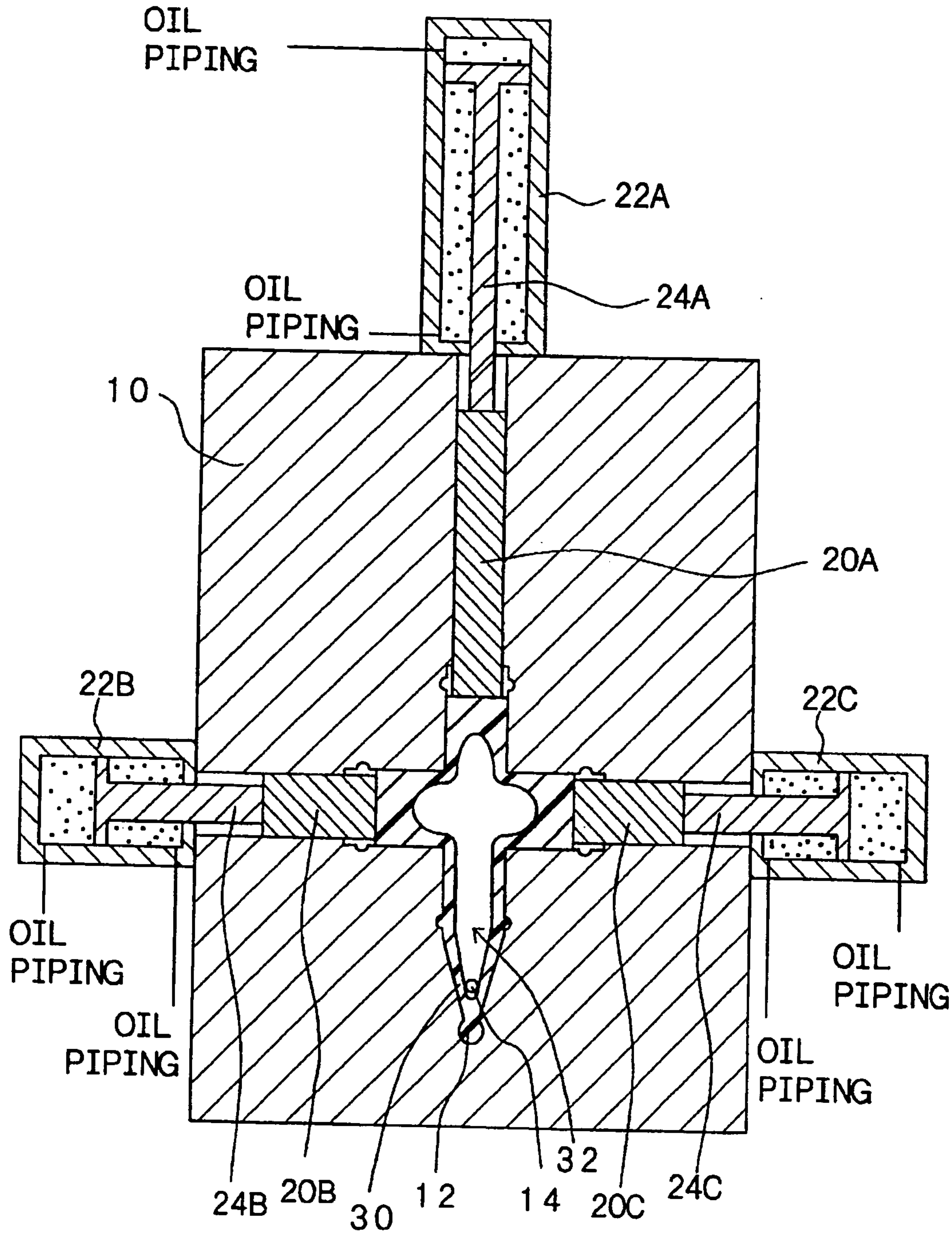
24B
20B
30
12
14
20C
24C

Fig. 15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PIPING
22A
OIL
PIPING
24A
10
20A
22B
22C
OIL
PIPING
OIL
PIPING
OIL
PIPING
OIL
PIPING
32
24B
20B
30
12
14
20C
24C

Fig. 16

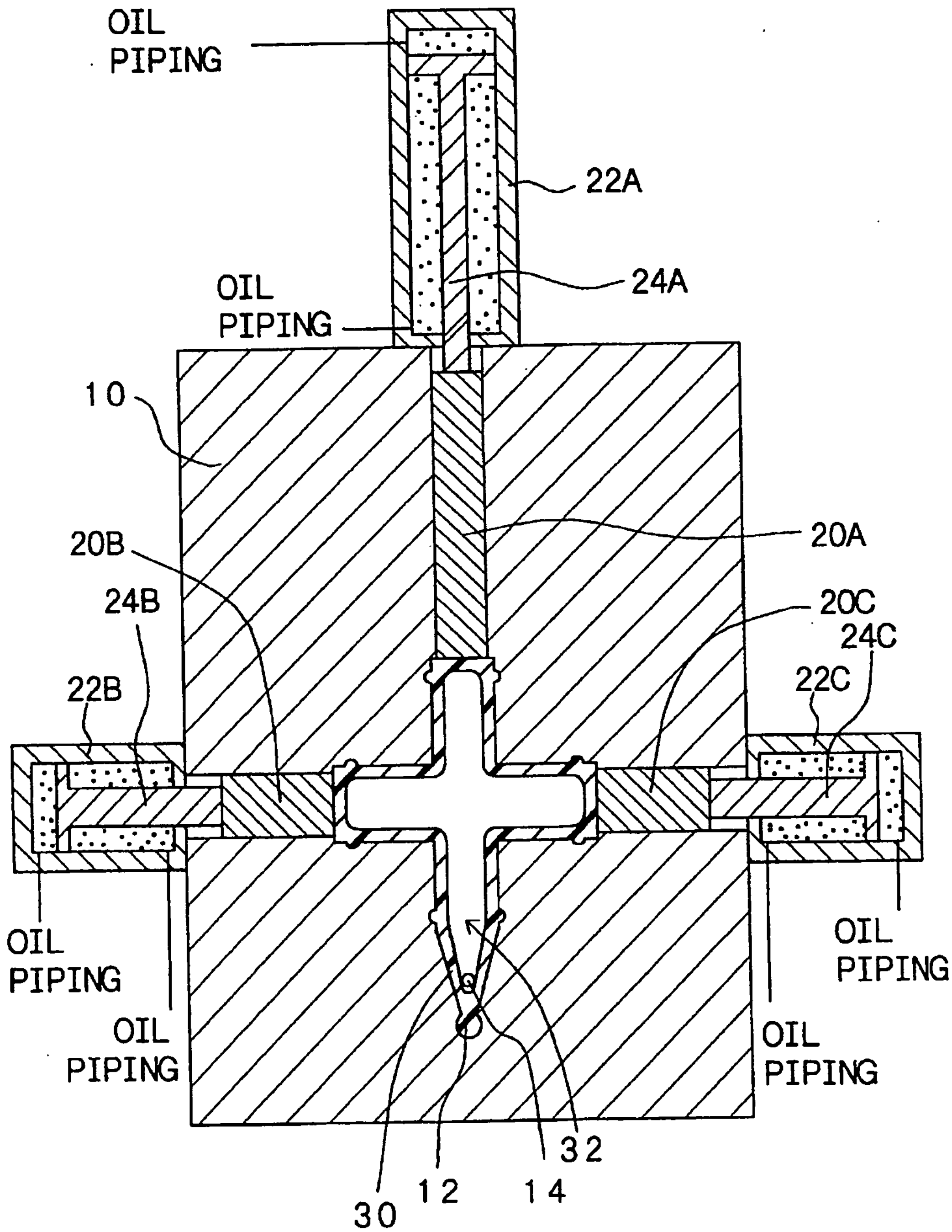

OIL PIPING
22A
24A
OIL PIPING
10
20A
20B
24B
20C
24C
22B
22C
OIL PIPING
OIL PIPING
OIL PIPING
OIL PIPING
32
30
12
14

Fig. 17A

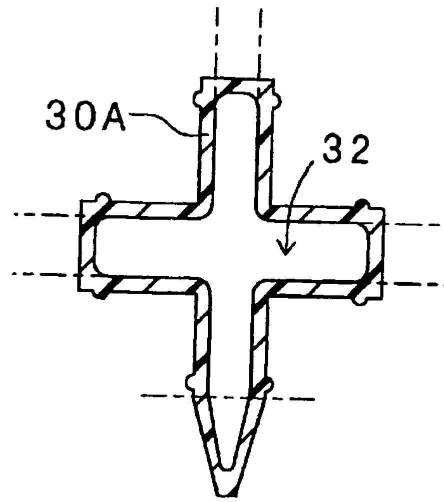


Fig. 17B

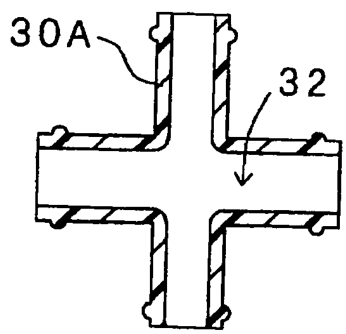


Fig. 17C

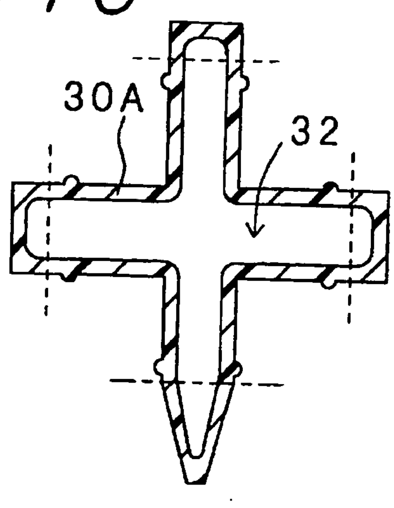


Fig. 18

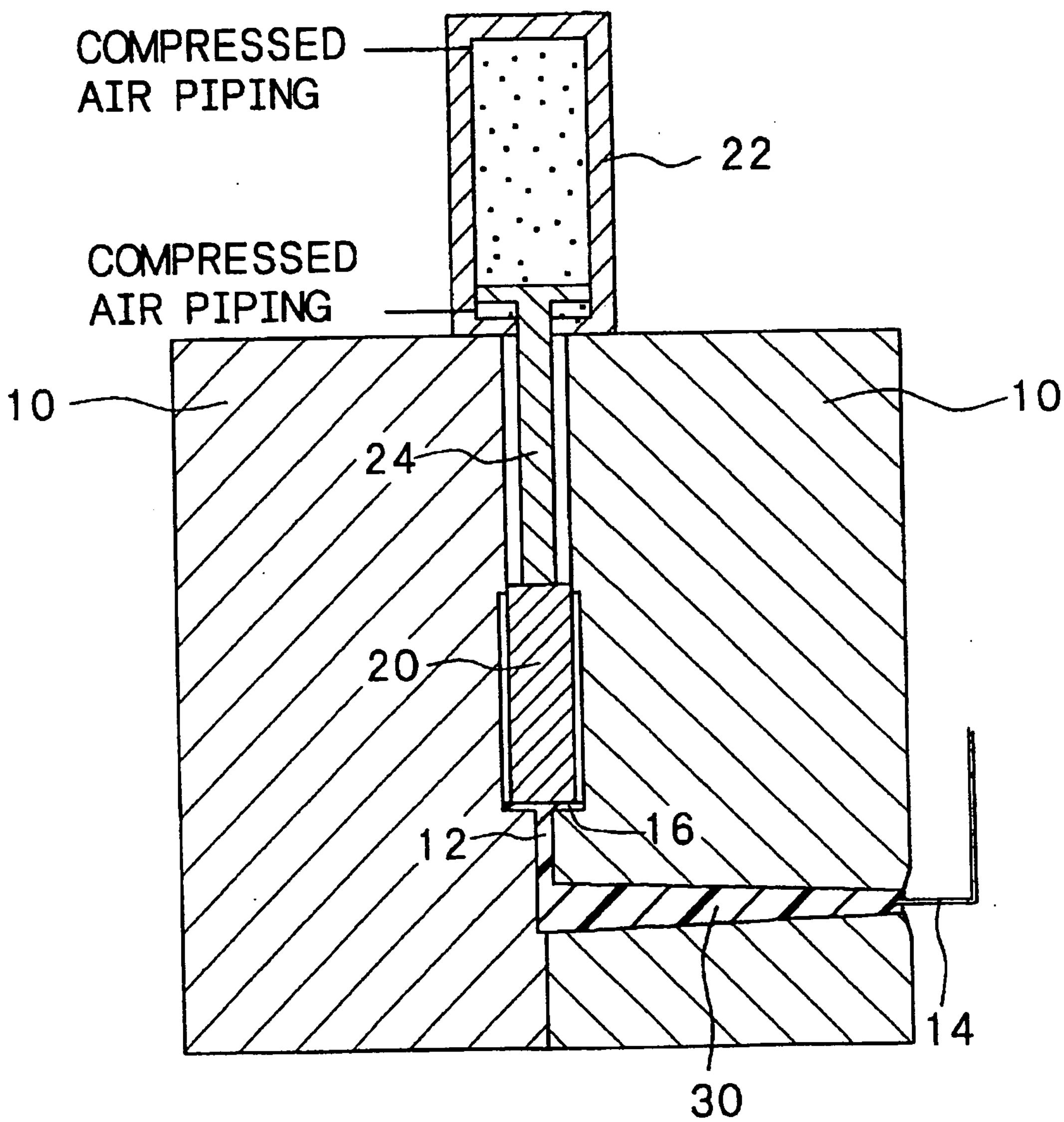

COMPRESSED AIR PIPING
22
COMPRESSED AIR PIPING
10
10
24
20
12
16
14
30

Fig. 19

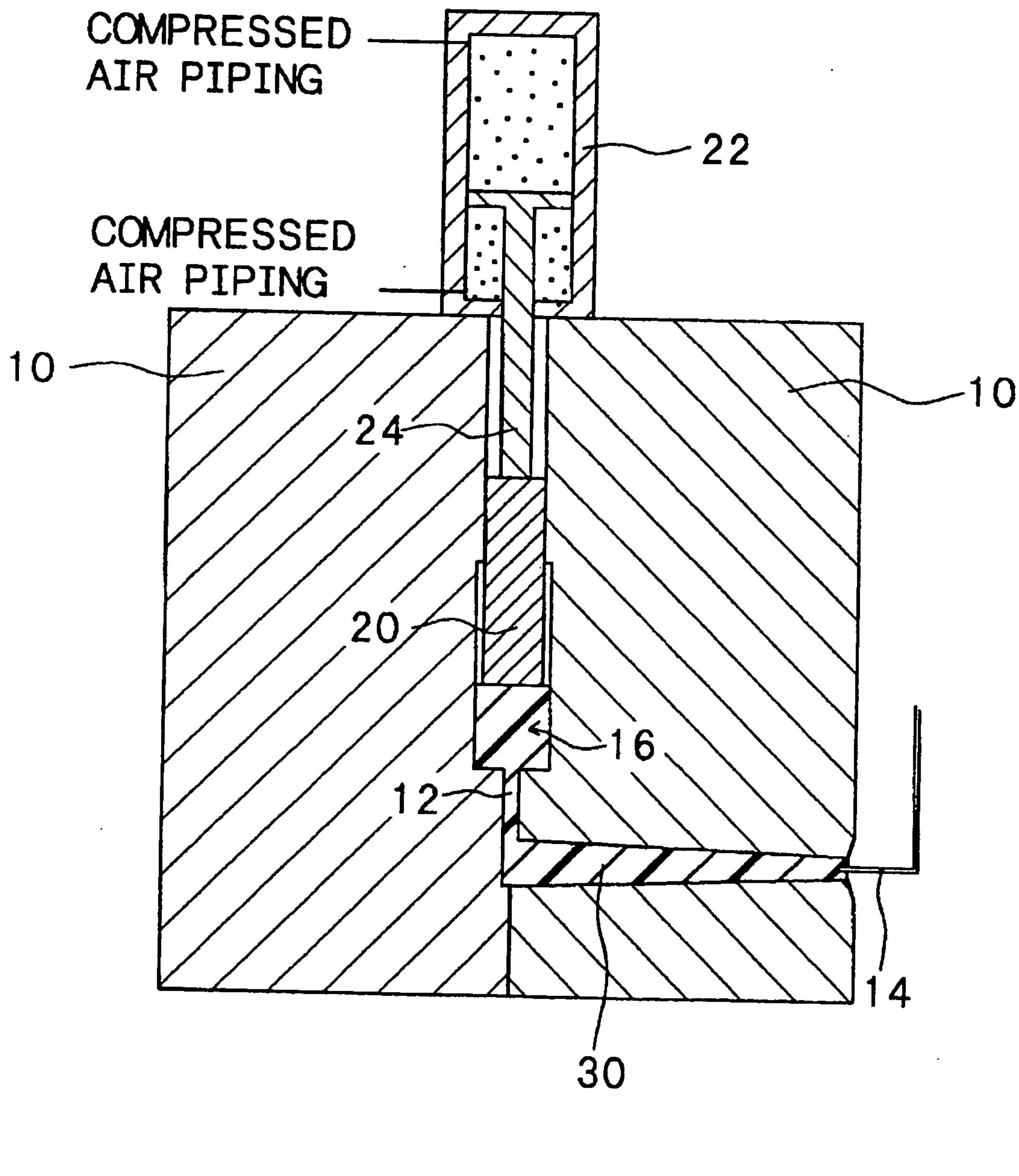

COMPRESSED AIR PIPING
22
COMPRESSED AIR PIPING
10
10
24
20
16
12
14
30

Fig. 20

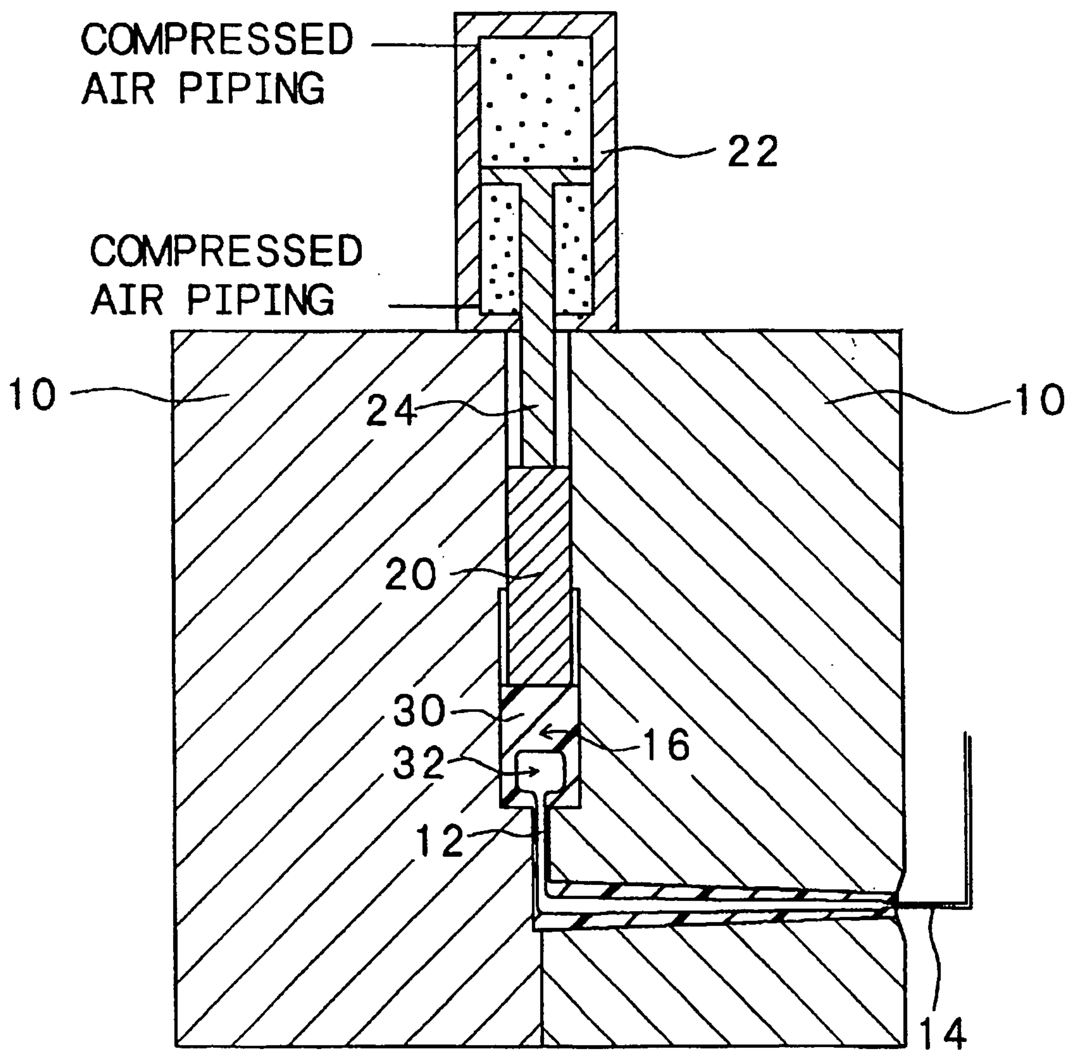

COMPRESSED AIR PIPING
22
COMPRESSED AIR PIPING
10
24
10
20
30
16
32
12
14

Fig. 21

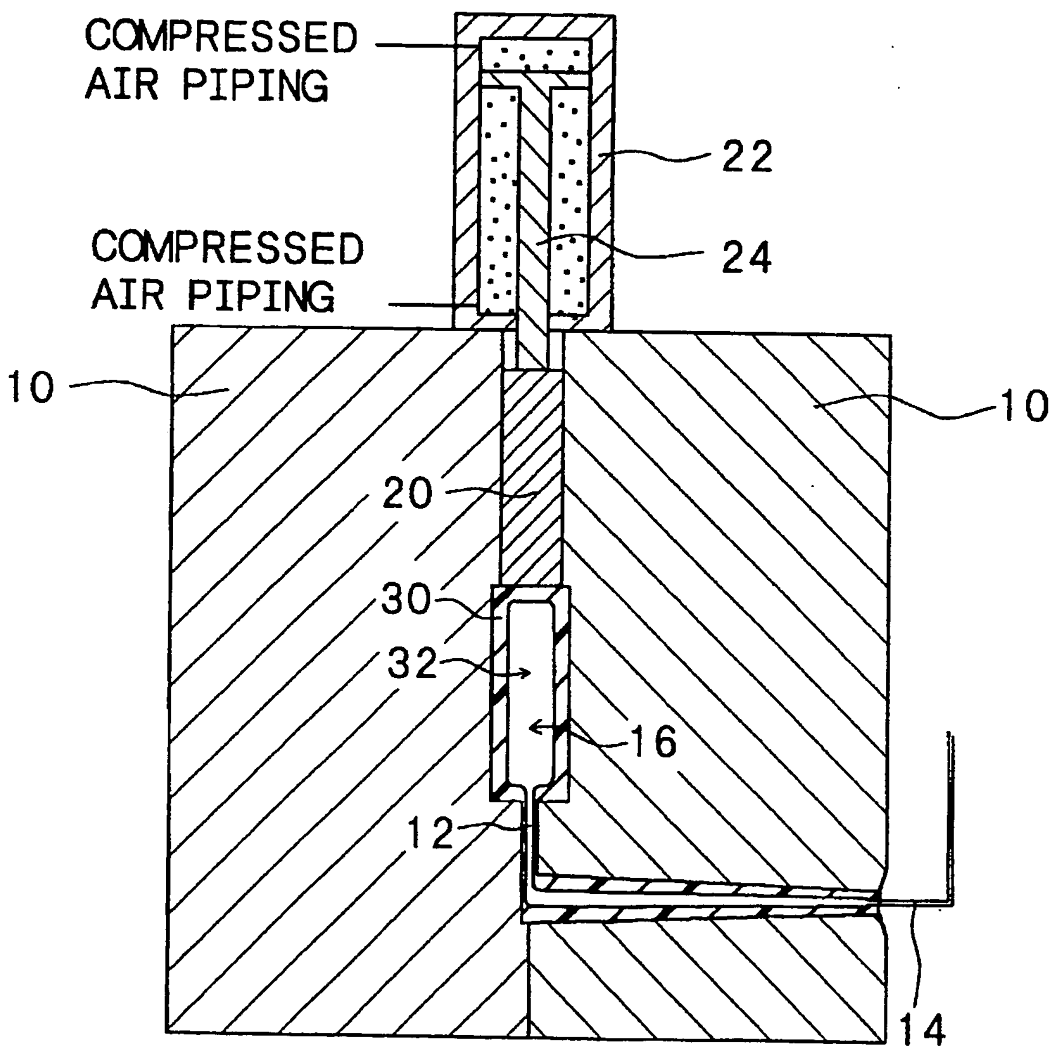

COMPRESSED
AIR PIPING
22
COMPRESSED
AIR PIPING
24
10
10
20
30
32
16
12
14

Fig. 22

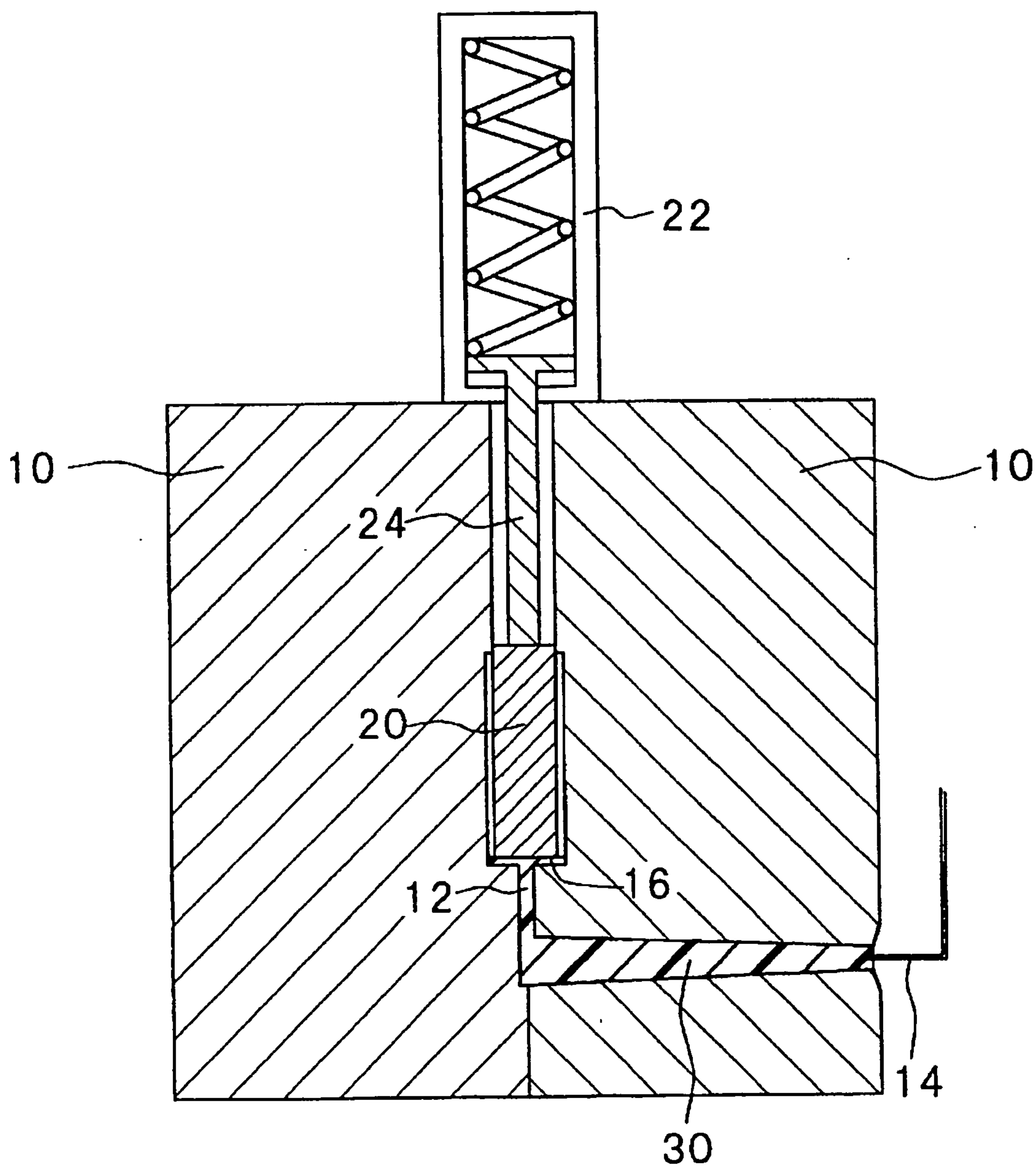


Fig. 23

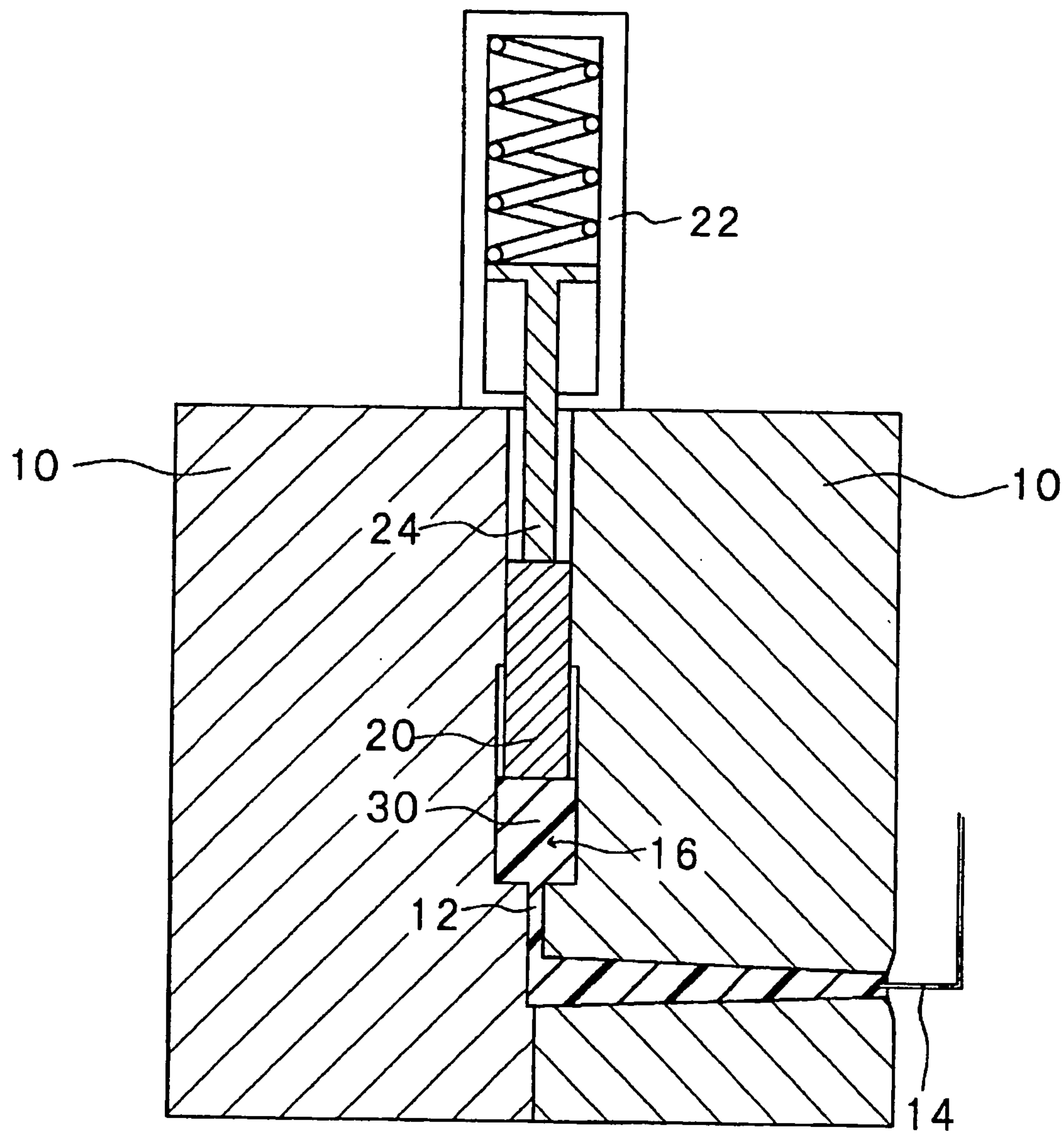


Fig. 24

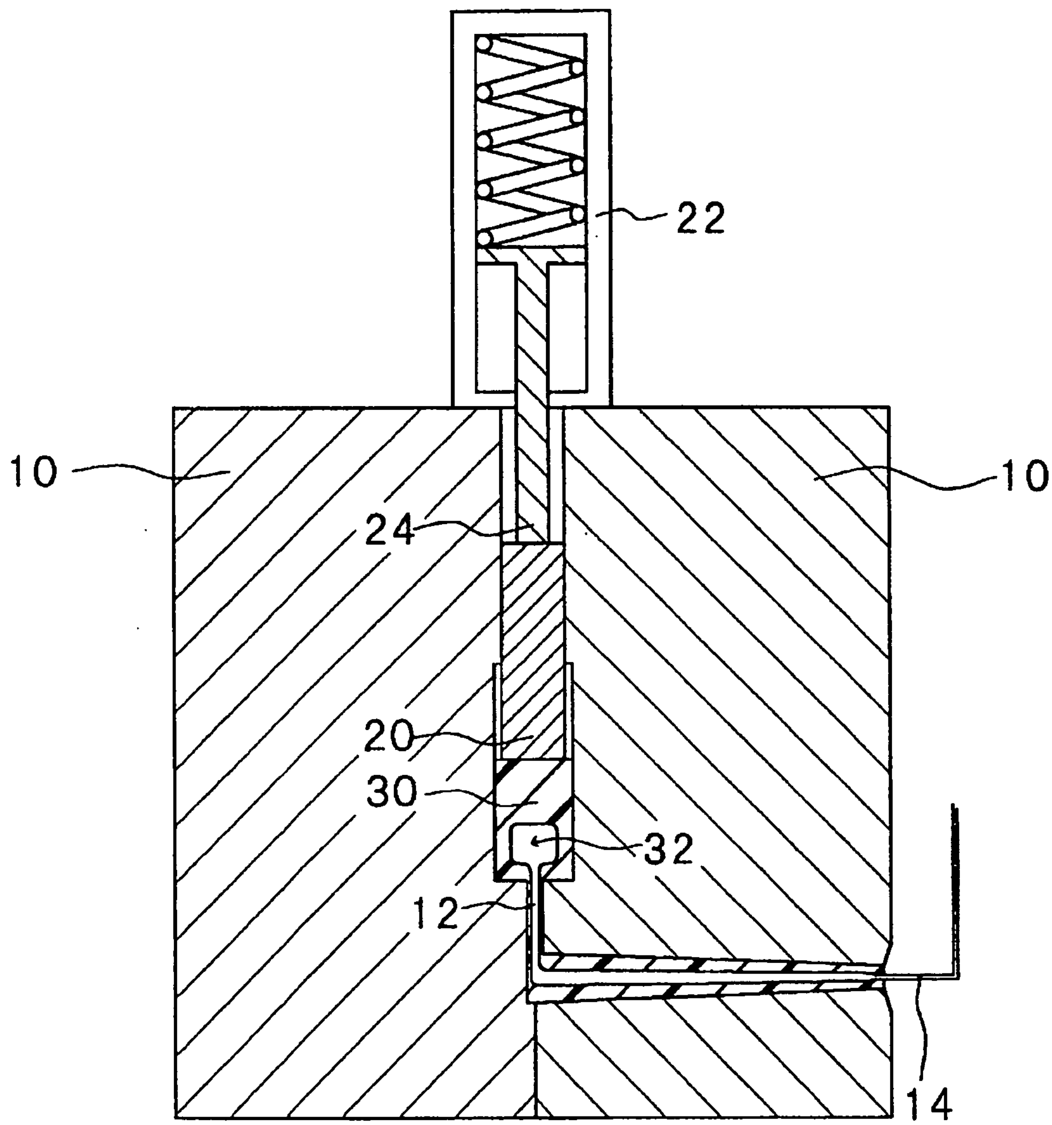


Fig. 25

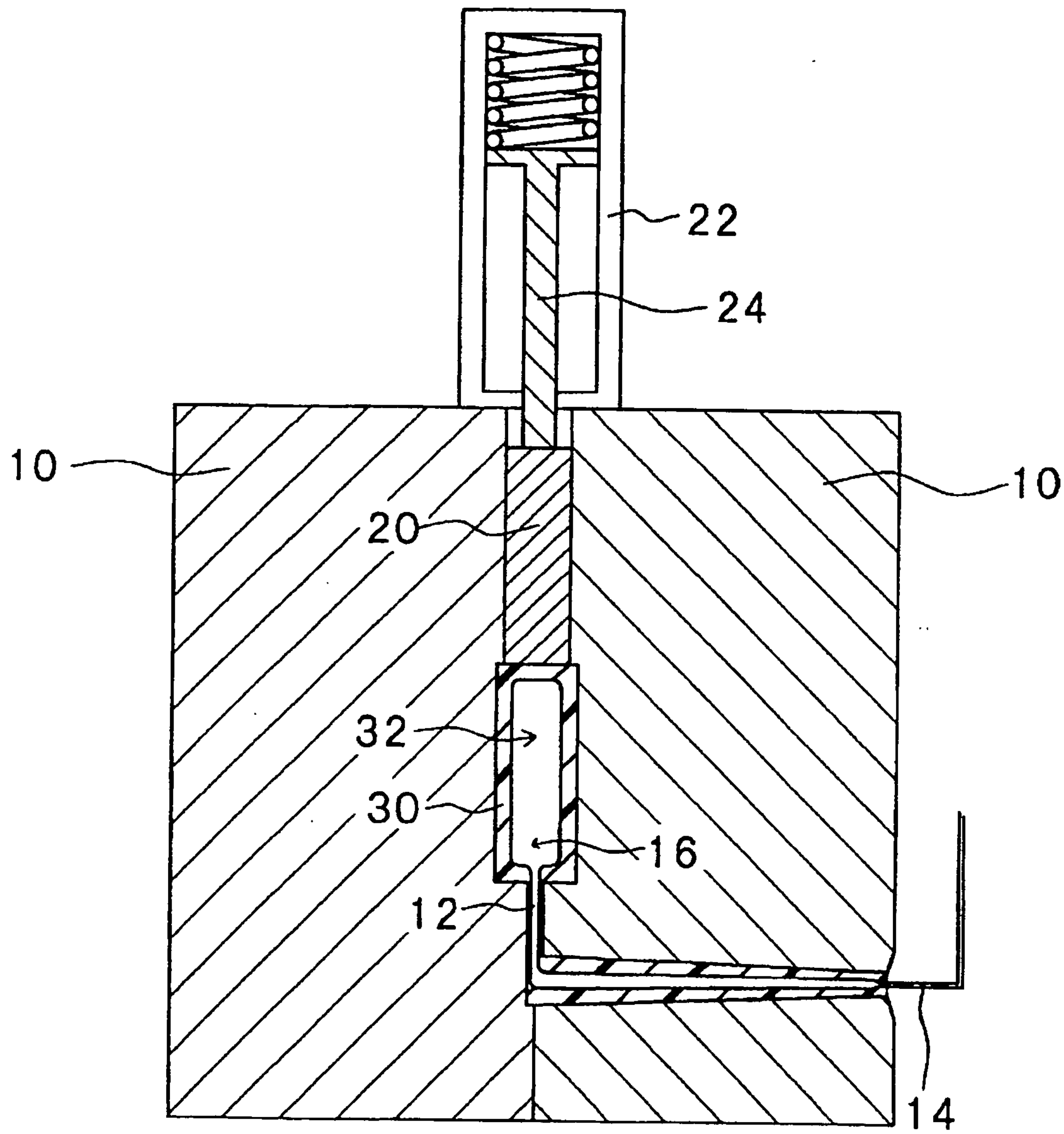


Fig. 26A

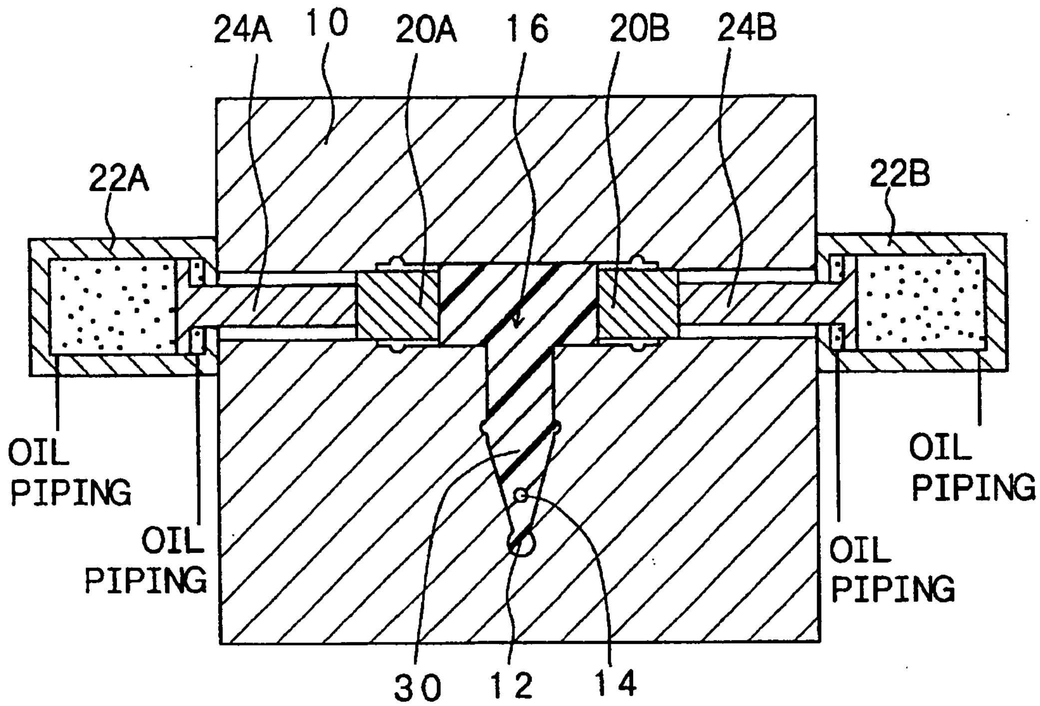


Fig. 26B

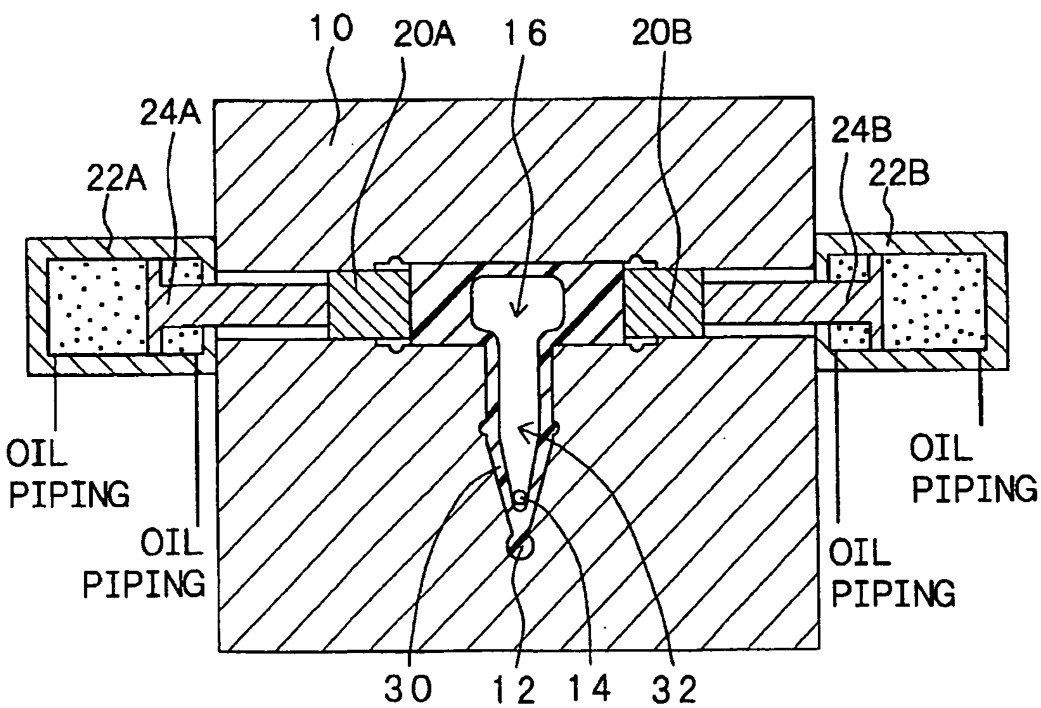


Fig. 27

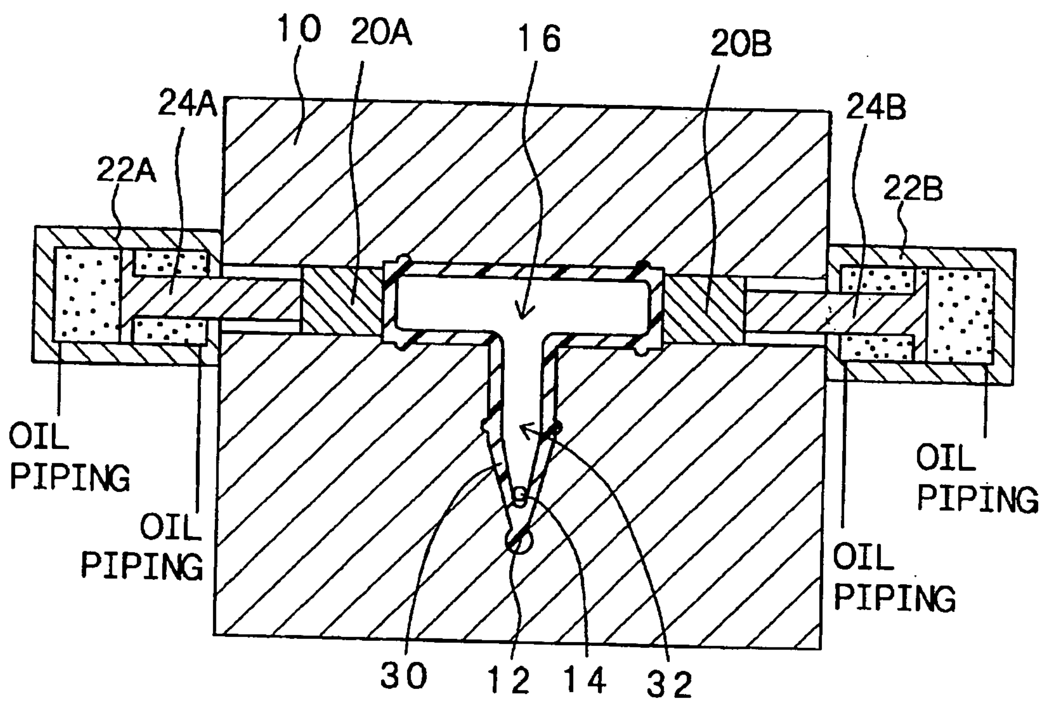

10
20A
16
20B
24A
24B
22A
22B
OIL PIPING
OIL PIPING
OIL PIPING
OIL PIPING
30
12
14
32

Fig. 28A

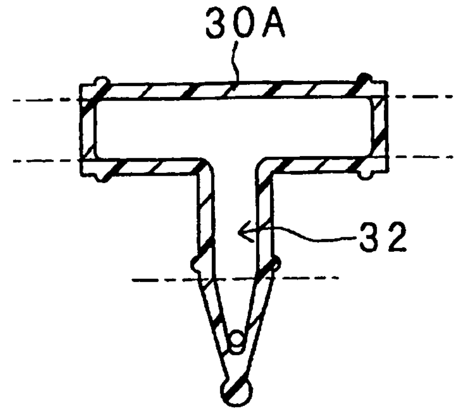


Fig. 28B

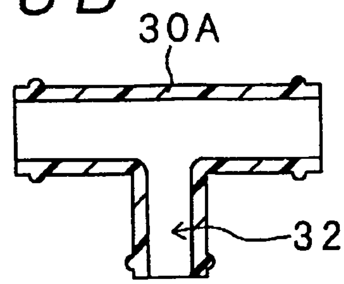


Fig. 28C

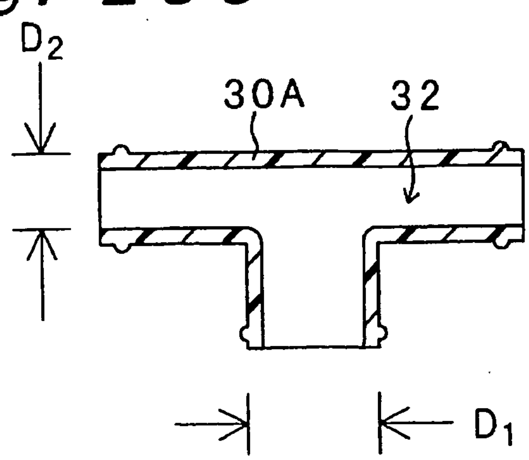


Fig. 29A

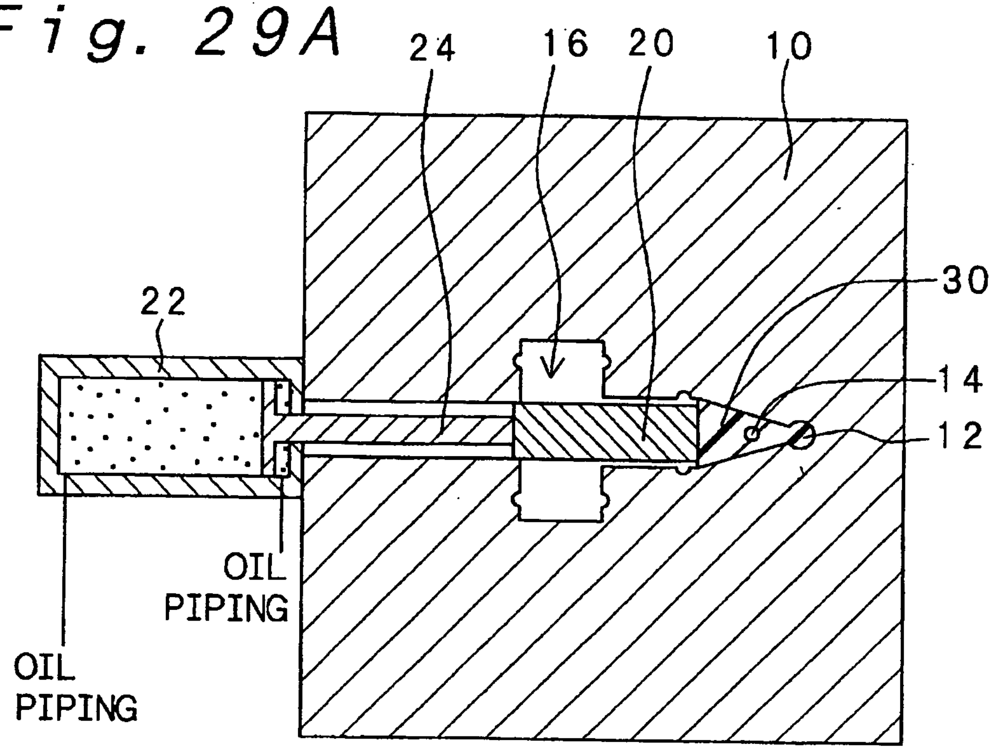


Fig. 29B

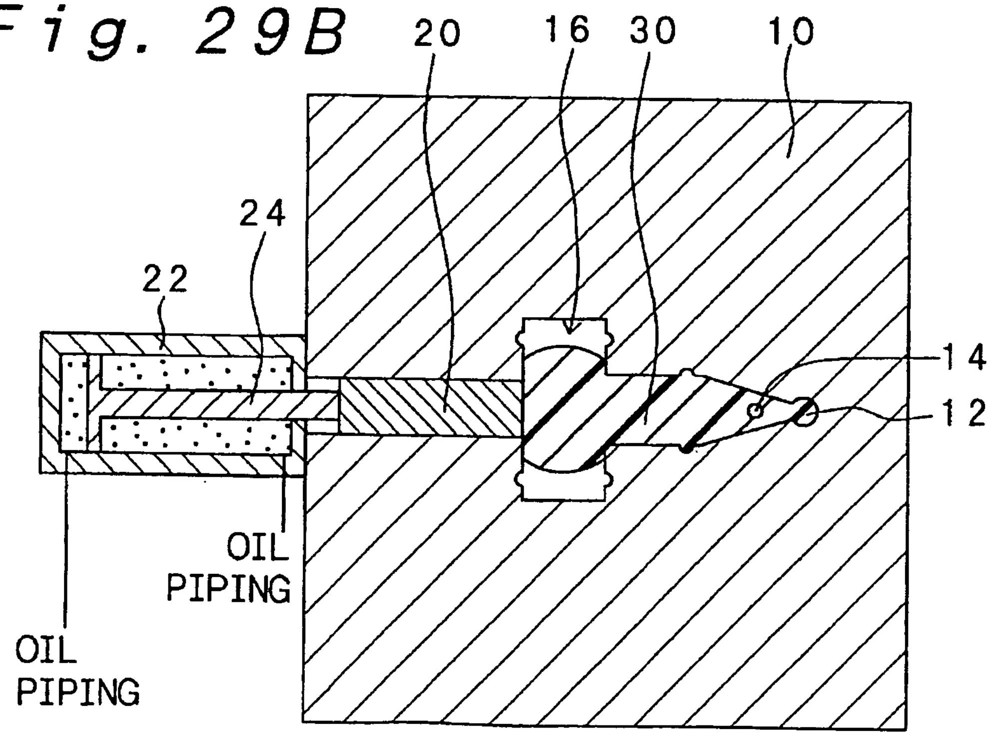


Fig. 30A

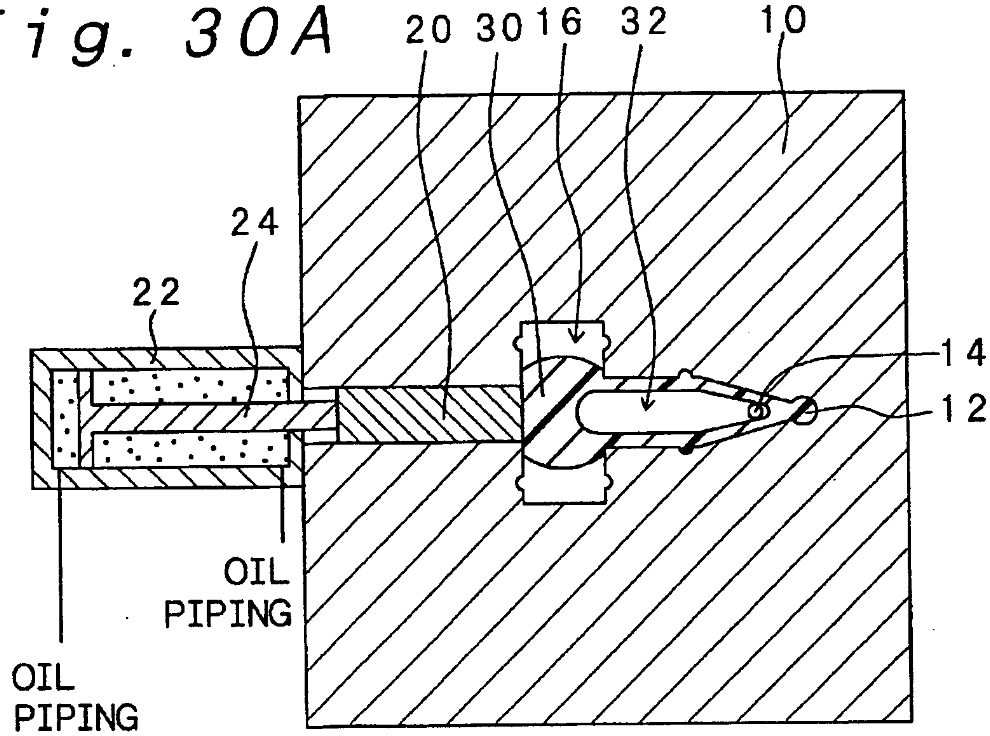


Fig. 30B

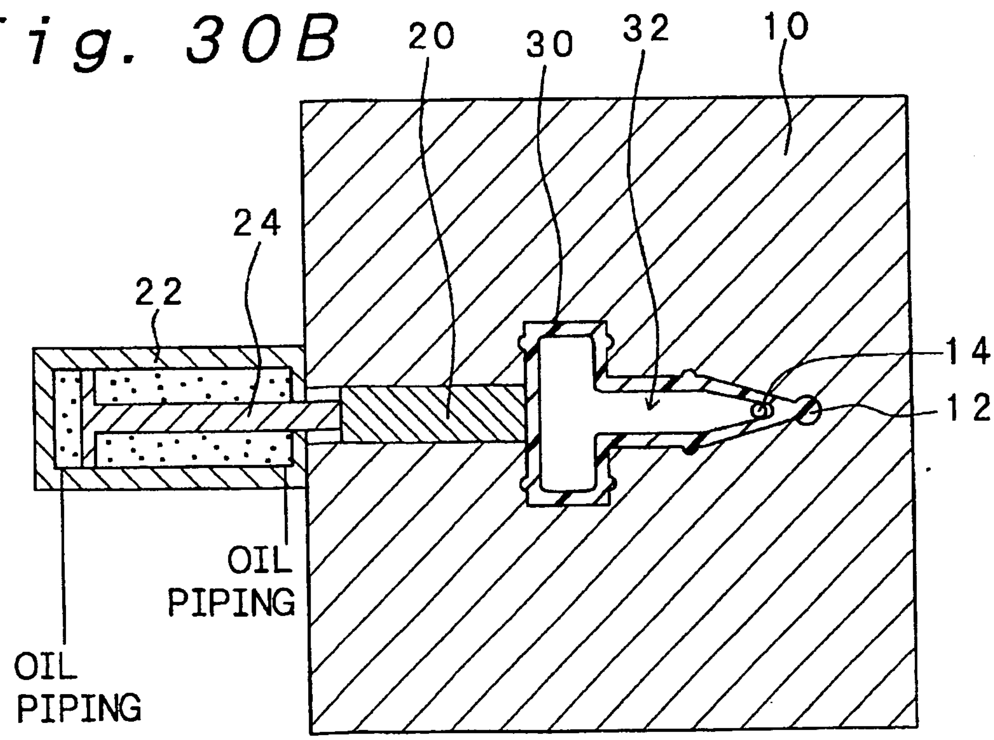


Fig. 31A

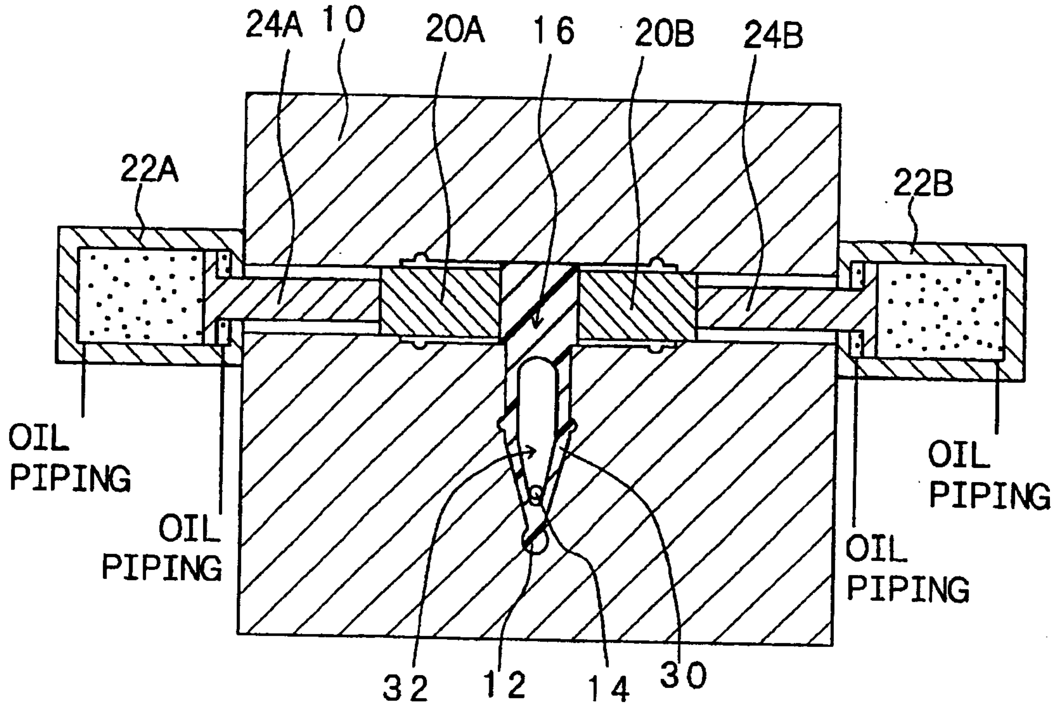


Fig. 31B

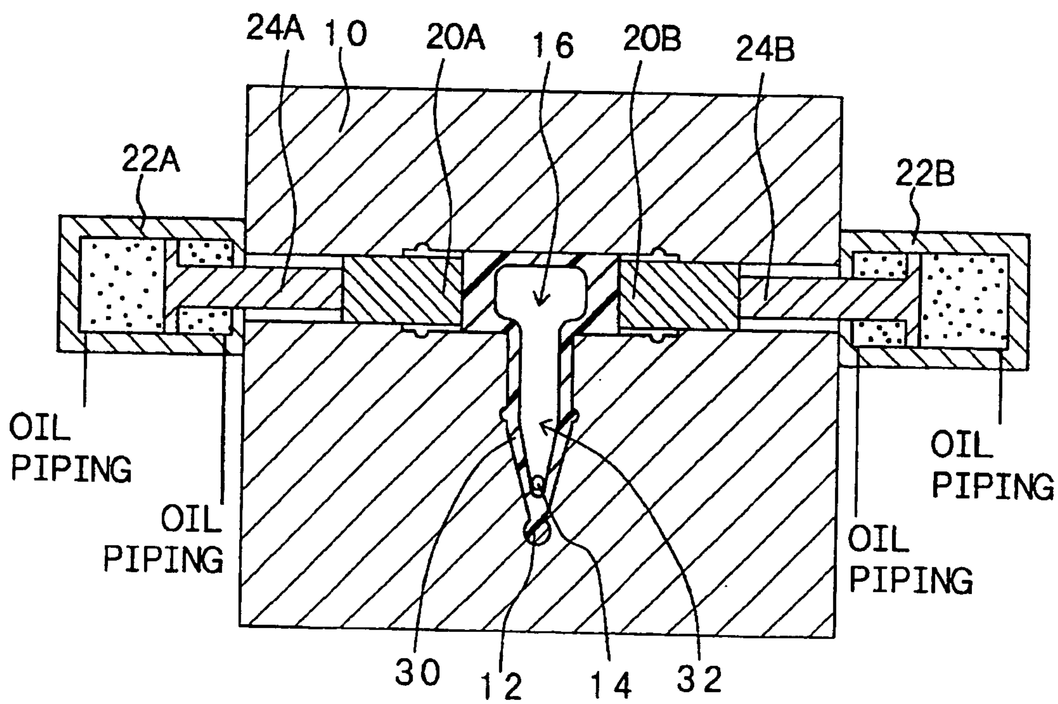


Fig. 32A

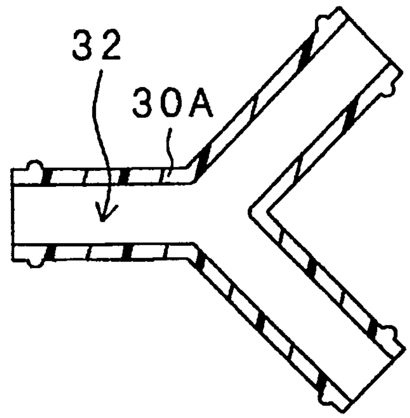


Fig. 32B

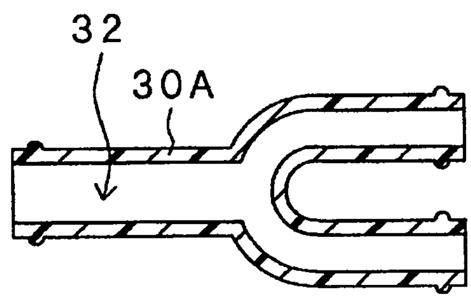


Fig. 32C

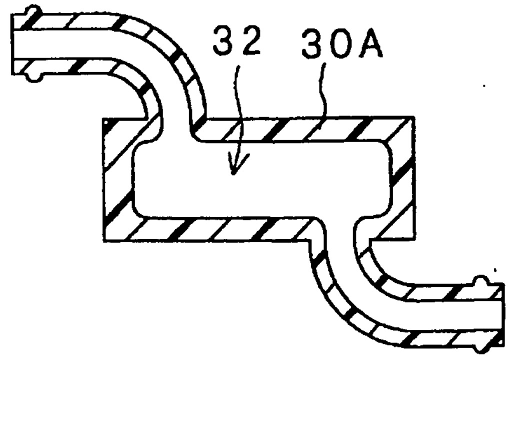


Fig. 33A

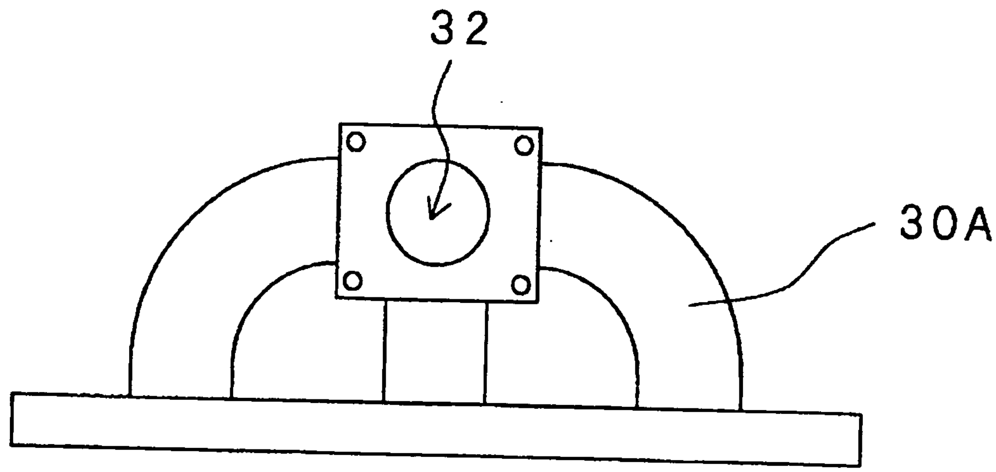
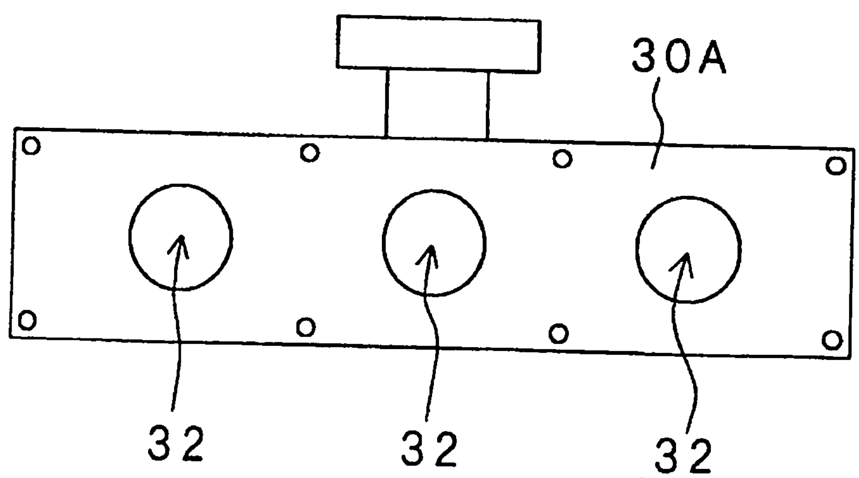


Fig. 33B



MOLD APPARATUS FOR PROCESS FOR INJECTION MOLDING

BACKGROUND OF THE INVENTION AND RELATED ART

The present invention relates to a mold apparatus suitable for injection-molding an article having a hollow structure, and a process for injection-molding an article having a hollow structure with the mold apparatus. Specifically, it relates to a mold apparatus which can effectively prevent "jetting" (also called "snake flow") in a molten resin injected into a cavity of a mold and is suitable for molding an article having an excellent appearance and a desired hollow structure therein, and a process for injection-molding such an article having a hollow structure with the mold apparatus. More specifically, it relates to a mold apparatus suitable for molding an article having a hollow structure which works, for example, as a path for the flow of a fluid, the hollow structure being a T-letter shaped manifold structure, a cross or "+" shaped manifold structure or a manifold structure for distributing a fluid in multi-directions, and a process for injection-molding an article having such a hollow structure with the mold apparatus.

For producing a molded article of a synthetic resin having a desired hollow structure, an injection molding method has recently increasingly come into wide use in which a pressurized fluid is introduced into a molten resin injected into a cavity of a mold to form a molded article having a hollow structure, since the so-formed article is almost free of a sink mark and distortion. This conventional injection molding method requires the use of a mold and an apparatus for introducing a pressurized fluid. Further, the mold is required to have a sprue portion and a runner portion for flowing a molten resin from a heating cylinder head of an injection molding machine to the cavity of the mold, and a gate portion is provided between the runner portion and the cavity.

An article having a manifold structure having a hollow structure which works as a path for the flow of a fluid is used, for example, as a tubing member, in various fields. An article of this type is used, for example, as a cooling tubing member for an engine, an intake manifold member for an engine, an exhaust gas tubing member or a hydraulic tubing member for a braking device in the fields of automobiles and motorcycles. Further, an article of the above type is used, for example, as a coolant tubing member for a refrigerator or a fluid-controlled actuator tubing member in the fields of electric appliances and machines. It is also used, for example, as a tubing member for a hot-water heater, a tubing member for a boiler, a tubing member for water supply or a tubing member for gas supply in the fields of construction and construction materials, or as a tubing member for a medical apparatus for a circulatory system or a tubing member for a medical apparatus for a respiratory system in the field of medicine.

Generally, the material forming an article having a manifold structure is a metal or a synthetic resin. When an article having a manifold structure is produced, for example, from a metal, a plurality of parts are assembled and welded. When an article having a manifold structure is produced, for example, from a synthetic resin, a plurality of parts are assembled, bonded and welded. For producing an article having a manifold structure by an injection molding method, there is known a method in which a core for forming a hollow structure is placed in a cavity of a mold and a molten resin is injected into a space formed by the cavity surface and the surface of the core. However, the problem of this method is that the mold structure is complicated. Further, there is known another method of forming a manifold structure by an injection molding method, in which a core of a water-soluble resin or a metal for forming a hollow structure is placed in a cavity of a mold, a molten resin is injected into a space formed by the cavity surface and the surface of the core, and then the core is dissolved in water or is removed by melting it. In this method, however, it is required to prepare a core of a water-soluble resin or a metal in advance, and it is required to remove the core after an article is formed, so that the production process is complicated. As explained above, in all the above-explained methods, a number of parts are required, the production process is complicated, an assembly step is required, and it is difficult to reduce the production cost. Further, the method of producing a manifold by the injection molding method with the core involves a problem of weld.

JP-A-6-262636 discloses a method of injection-molding a pipe-shaped article having a plurality of branches. In this injection molding method, no complicated mold structure is required. While a molten resin is injected into a cavity of a mold for producing a branched pipe, a pressurized gas is introduced through branch ends to form a pipe-shaped article. This injection molding method is, in principle, is a method for improving the appearance of an article (overcoming a sink mark and distortion) by introducing a pressurized gas into a molten resin, or a so-called gas-assisted injection molding method.

When an attempt is made to produce a molded article of a synthetic resin having an excellent appearance by a conventional injection molding method, and when the area of the cross-section of the cavity of a mold, which is perpendicular to the flow of a molten resin, is largely different in size from the area of the cross section of a gate portion, jetting takes place in a molten resin injected into the cavity, and the appearance and function of the molded article is greatly impaired to decrease the product value of the article.

For obtaining a molded article of a synthetic resin having improved physical properties such as high strength, high impact strength, high fatigue resistance, high creep resistance, high heat resistance, high hot water resistance, high oil resistance, high chemical resistance, etc., it is required to use a synthetic resin of high melt-viscosity such as a synthetic resin of having high molecular weight, a crosslinkable synthetic resin or a synthetic resin alloy. However, the problem of the use of the above resins is that jetting is liable to occur, so that it is difficult to obtain a desired molded article having an excellent appearance.

The method of introducing a pressurized fluid into a molten resin injected into a cavity of a mold is largely classified into a so-called full shot method in which a pressurized fluid is introduced after the cavity is completely filled with a molten resin and a so-called short shot method in which a pressurized fluid is introduced while the cavity is not completely filled with a molten resin. In particular, the short shot method has a problem in that when a spiral (coil-like) jetting occurs, it is difficult to introduce a pressurized fluid into a molten resin (in an amount insufficient for completely filling the cavity) injected into the cavity, and the pressurized fluid sometimes blows off the molten resin in the cavity so that no desired molded article is obtained.

For preventing the occurrence of jetting, there has been proposed a method in which the cross-sectional area of a gate portion is increased, or the injection rate of a molten

resin is decreased, or the temperature of a molten resin is increased, or a resin having a low melt viscosity is selected. However, when the cross-sectional area of a gate portion is increased, it requires an additional cost to post-treat the gate-corresponding portion of the article. When the injection rate is decreased, the molding cycle is long so that the production cost increases. When the temperature of a molten resin is increased, the heat stability of the molten resin is impaired and the molten resin generates a gas or the resin has a decreased molecular weight so that the molded article has a poor appearance or decreased properties. Further, the method of selecting a resin having a low melt viscosity is not an essential solution for obtaining a molded article having high impact strength and high fatigue resistance, since, for these purposes, it is required to use a resin having a high melt viscosity such as a synthetic resin of high molecular weight, a crosslinkable synthetic resin or a synthetic resin alloy.

The injection molding method disclosed in JP-A-6-262636 is very effective for producing a pipe-like article having a plurality of branches. However, a pressurized gas is sometimes not properly introduced into a molten resin, and a molded article having a desired hollow structure is not always obtained. This phenomenon is liable to take place when a synthetic resin having a high melt viscosity or a synthetic resin reinforced with a reinforcing material such as a glass fiber is used. For obtaining a molded article of a synthetic resin having improved physical properties such as high strength, high impact strength, high fatigue resistance, high creep resistance, high heat resistance, high hot water resistance, high oil resistance, high chemical resistance, etc., it is required to select a resin from synthetic resins having a high melt viscosity such as a synthetic resin of high molecular weight, a crosslinkable synthetic resin, resins prepared by incorporating a reinforcing material into these resins, and a synthetic resin alloy. However, when the above resins are used, it is sometimes difficult to obtain a molded article having a desired hollow structure.

OBJECT AND SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a mold apparatus suitable for the reliable production of a molded article of a synthetic resin having an excellent appearance and a desired hollow structure in a short and stable molding cycle without any influence caused by the synthetic resin used, and a process for injection molding an article having a hollow structure with the mold apparatus.

The above object and advantages of the present invention are achieved, first, by a mold apparatus having a mold provided with a cavity, for use with an injection molding machine, for producing a molded article having a hollow structure by introducing a pressurized fluid into a molten resin in the cavity while or after the molten resin is injected into the cavity, and cooling and solidifying the molten resin in the cavity to form a hollow structure in the molded article,

Said mold apparatus comprising

(A) at least one plug which is provided in the cavity of the mold and is movable nearly in parallel with a flow-axis direction of the molten resin,

(B) a plug-moving means for moving the plug,

(C) a resin injection portion for injecting the molten resin into the cavity, and

(D) a pressurized fluid introducing portion for introducing the pressurized fluid into the molten resin injected into the cavity.

In the mold apparatus of the present invention, the surface of the plug which is to contact with a molten resin is preferably smooth-finished. When the contact surface of the plug has a high roughness, it is difficult to separate the contact surface from the solidified resin, and it is therefore difficult to move the plug smoothly, so that it is difficult to obtain an intended molded article.

The form of the plug cannot be uniquely determined, while it can be properly determined on the basis of the properties of a resin used and the form of an intended hollow structure. The plug has such a form that the plug can move in the cavity. For preventing the occurrence of the defects on a molded article surface caused by jetting and a flow mark, the cross-sectional form of the plug in the perpendicular direction to the moving direction of the plug is preferably generally the same as or similar to the cross-sectional form of the cavity in the perpendicular direction. The clearance between the plug surface and the cavity surface is required to be such a clearance that the plug does not contact the cavity surface. Preferably, a molten resin does not penetrate the above clearance, while a molten resin may penetrate the clearance in some cases.

The mold apparatus of the present invention may have a structure in which a sprue portion and a runner portion as a flow path through which the molten resin flows are provided between a heating cylinder end of an injection molding machine and the cavity and a gate portion is provided between the runner portion and the cavity, or may have a structure in which a molten resin is directly injected into the cavity through a hot runner or a valve gate. A whole of the above gate portion, the above hot runner, the above valve gate, etc., is called a resin injection portion. Further, when a molded article varies in thickness, specifically from a thin portion to a thick portion, that portion of a cavity which forms the thin portion of the molded article is included in the resin injection portion when the forward end position of the plug comes close to that portion of the cavity which forms the thin portion.

A pressurized fluid introducing device for introducing a pressurized fluid may be a gas injection nozzle which is provided with at least one non-return valve on its top portion and whose forward end can communicate with the pressurized fluid introducing portion, and apart from that portion with a moving means.

The mold of the present invention may be a mold with which one molded article is produced in one operation or may be a mold with which a plurality of molded articles are produced in one operation.

In one aspect of the mold apparatus of the present invention, when the plug is positioned in its forward end position, the plug is preferably positioned close to the resin injection portion. Although depending upon the form of a molded article, "the plug being positioned close to the resin injection portion" generally means that the top end portion of the plug opposite to the resin injection portion is positioned 0 mm to 20 mm apart from the resin injection portion when the plug is positioned its forward end position. When the plug is positioned in its forward end position, the plug may be positioned so that the top end portion of the plug contacts the cavity surface to shut the resin injection portion. If the plug is positioned in its forward end position but is considerably apart from the resin injection portion, the space formed by the cavity surface and the plug is so large that a molten resin injected into the cavity does not collide with the plug so sufficiently as to be prevented from going forward, and the occurrence of jetting is sometimes not effectively prevented.

The above object and advantages of the present invention are achieved, second, by an injection molding process of the

present invention, the first to fourth aspects of which use an injection molding machine equipped with a mold apparatus comprising

(A) at least one plug which is provided in the cavity of the mold and is movable nearly in parallel with a flow-axis direction of a molten resin,

(B) a plug-moving means for moving the plug,

(C) a resin injection portion for injecting the molten resin into the cavity, and

(D) a pressurized fluid introducing portion for introducing a pressurized fluid into the molten resin injected into the cavity.

The first aspect of the injection molding process of the present invention is directed to a process for the production of a molded article by introducing the pressurized fluid into the molten resin in the cavity of the mold through the pressurized fluid introducing portion while or after the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the molded article, said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity with the plug-moving means before the molten resin is injected,

(b) moving the plug toward its backward end position nearly in parallel with a flow-axis direction of the molten resin, with the plug-moving means or under a pressure of the injected molten resin, after the injection of the molten resin is initiated,

(c) introducing the pressurized fluid into the molten resin in the cavity through the pressurized fluid introducing portion while the plug is moving, and

(d) moving the plug up to its backward end position nearly in parallel with the flow-axis direction of the molten resin with the plug-moving means or under the pressure of the molten resin and/or the pressurized fluid introduced into the molten resin, and then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

FIGS. 1A to 1F and FIGS. 2A to 2D schematically show the timing of movement (sliding) of the plug, the timing of injection of the molten resin, and the timing of introduction of the pressurized fluid. In FIGS. 1A to 1F and FIGS. 2A to 2D, the left end of a line segment indicated by "INJECTION OF MOLTEN RESIN" shows the initiation of the injection, and its right end shows the termination of the injection. The left end of a line segment indicated by "INTRODUCTION OF PRESSURIZED FLUID" shows the initiation of the introduction of the pressurized fluid, and its right end shows the termination of the introduction of the pressurized fluid. The left end of a line segment indicated by "MOVEMENT OF PLUG" shows the initiation of the movement of the plug, and its right end shows the termination of the movement of the plug. The length of the line segment schematically shows a period of time.

In the first aspect of the injection molding process of the present invention, as shown in FIGS. 1A and 1B, the pressurized fluid is introduced into the molten resin during the injection of the molten resin into the cavity. Further, as shown in FIGS. 1A and 1B, the movement (sliding) of the plug is initiated after the injection of the molten resin into the cavity is initiated but before the introduction of the pressurized fluid into the molten resin in the cavity is initiated. The movement of the plug to its backward end position may be completed before the injection of the molten resin into the cavity is completed as shown in FIG. 1A, it may be completed after the injection of the molten resin into the cavity is completed as shown in FIG. 1B, or it may be completed at a time when the injection of the molten resin into the cavity is completed.

Otherwise, as shown in FIG. 1C, the pressurized fluid is introduced into the molten resin in the cavity after or at a time when the injection of the molten resin into the cavity is completed, and the movement (sliding) of the plug is initiated before the injection of the pressurized fluid into the cavity is initiated. The movement of the plug to its backward end position is completed after the injection of the molten resin into the cavity is completed and during the introduction of the pressurized fluid into the molten resin as shown in FIG. 1C.

In these cases, the movement (sliding) of the plug may be initiated at a time when the injection of the molten resin into the cavity is initiated, and the introduction of the pressurized fluid may be initiated at a time when the movement of the plug is initiated.

The second aspect of the injection molding process of the present invention is directed to a process for the production of a molded article by introducing the pressurized fluid into the molten resin in the cavity of the mold through the pressurized fluid introducing portion while or after the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the molded article, said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity with the plug-moving means before the molten resin is injected,

(b) moving the plug toward its backward end position nearly in parallel with a flow-axis direction of the molten resin, with the plug-moving means or under a pressure of the injected molten resin, after the injection of the molten resin is initiated, and allowing the plug to arrive at its backward end position during the injection of the molten resin or after the injection of the molten resin is completed,

(c) introducing the pressurized fluid into the molten resin in the cavity through the pressurized fluid introducing portion, and

(d) then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

FIGS. 1D to 1F schematically show the timing of the movement (sliding) of the plug, the timing of injection of the molten resin, and the timing of introduction of the pressurized fluid in the injection molding process according to the second aspect of the present invention. In the second aspect of the present invention, the pressurized fluid is introduced into the molten resin during the injection of the molten resin into the cavity, as shown in FIG. 1D. Then, after the injection of the molten resin into the cavity is initiated and before the introduction of the pressurized fluid into the molten resin in the cavity is initiated, the movement (sliding) of the plug is initiated. The plug arrives at its backward end position before the introduction of the pressurized fluid into the molten resin is initiated as shown in FIG. 1D.

Otherwise, as shown in FIGS. 1E and 1F, the introduction of the pressurized fluid into the molten resin in the cavity is initiated after or at a time when the injection of the molten resin into the cavity is completed. And, as shown in FIGS. 1E or 1F, the movement (sliding) of the plug is initiated after the injection of the molten resin into the cavity is initiated and before the introduction of the pressurized fluid into the molten resin in the cavity is initiated. The plug arrives at its backward end position before the injection of the molten

resin is completed as shown in FIG. 1E, it arrives at its backward end position after the injection of the molten resin is completed as shown in FIG. 1F, or it arrives at its backward end position at a time when the injection of the molten resin is completed.

In these cases, the movement (sliding) of the plug may be initiated at a time when the injection of the molten resin into the cavity is initiated. Further, the injection of the pressurized fluid may be initiated at a time when the plug has arrived at its backward end position.

The third aspect of the injection molding process of the present invention is directed to a process for the production of a molded article by introducing the pressurized fluid into the molten resin in the cavity of the mold through the pressurized fluid introducing portion while the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the molded article, said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity with the plug-moving means before the molten resin is injected,

(b) moving the plug toward its backward end position nearly in parallel with a flow-axis direction of the molten resin, with the plug-moving means or under a pressure of the injected molten resin and/or a pressure of the pressurized fluid introduced into the molten resin, while the molten resin is injected into the cavity and while the pressurized fluid is introduced into the molten resin, and allowing the plug to arrive at its backward end position during the introduction of the pressurized fluid, and

(c) then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

FIGS. 2A and 2B schematically show the timing of the movement (sliding) of the plug, the timing of introduction of the molten resin, and the timing of injection of the pressurized fluid in the injection molding process according to the third aspect of the present invention. In the third aspect of the present invention, the introduction of the pressurized fluid into the molten resin is initiated while the molten resin is injected into the cavity as shown in FIGS. 2A and 2B. The movement (sliding) of the plug is initiated after the introduction of the pressurized fluid into the molten resin is initiated as shown in FIGS. 2A and 2B. The plug may arrive at its backward end position before the injection of the molten resin is completed as shown in FIG. 2A, it may arrive at its backward end position after the injection of the molten resin is completed as shown in FIG. 2B, or it may arrive at its backward end position at a time when the injection of the molten resin is completed. In these cases, the movement (sliding) of the plug may be initiated at a time when the introduction of the pressurized fluid into the molten resin is initiated.

The fourth aspect of the injection molding process of the present invention is directed to a process for the production of a molded article by introduction the pressurized fluid into the molten resin in the cavity of the mold through the pressurized fluid introducing portion after the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the molded article, said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity so as to allow the plug to stand against a pressure of the molten resin to be injected, with the plug-moving means before the molten resin is injected,

(b) maintaining the plug in its forward end position with the plug-moving means during the injection of the molten resin through the resin injection portion,

(c) moving the plug toward its backward end position nearly in parallel with a flow-axis direction of the molten resin, with the plug-moving means or under a pressure of the pressurized fluid, after the injection of the molten resin is completed and after or before the introduction of pressurized fluid is initiated, and allowing the plug to arrive at its backward end position during the introduction of the pressurized fluid, and

(d) then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

FIGS. 2C and 2D schematically show the timing of the movement (sliding) of the plug, the timing of injection of the molten resin, and the timing of introduction of the pressurized fluid in the injection molding process according to the fourth aspect of the present invention. In the fourth aspect of the present invention, the introduction of the pressurized fluid into the molten resin is initiated after (or at a time when) the injection of the molten resin into the cavity is completed as shown in FIGS. 2C and 2D. The movement (sliding) of the plug is initiated after (or at a time when) the introduction of the pressurized fluid into the molten resin is initiated as shown in FIG. 2C, or the movement (sliding) of the plug is initiated after (or at a time when) the injection of the molten resin into the cavity is completed and before the introduction of the pressurized fluid into the molten resin is initiated as shown in FIG. 2D. The plug arrives at its backward end position during the introduction of the pressurized fluid into the molten resin.

In the first to fourth aspects of the injection molding process of the present invention, preferably, the amount of the molten resin injected into the cavity is smaller than the amount which fully fills the cavity, and is sufficient for forming a molded article when the pressurized fluid is introduced into the molten resin.

In one embodiment of the first to fourth aspects of the injection molding process of the present invention, when the plug is positioned in its forward end position, the plug is preferably positioned close to the resin injection portion.

In the mold apparatus or the injection molding process of the present invention, the plug-moving means may be composed of a hydraulic cylinder, a pneumatic cylinder, a hydraulically actuated motor, a pneumatically actuated motor or an electric servo-motor, to directly move (slide) the plug, may be composed of a combination of any one of the above cylinders or motors with a screw mechanism such as a ball screw, a cam mechanism or a rack and pinion mechanism, or may be composed of various springs, while the plug-moving means is preferably composed of a hydraulic cylinder, a pneumatic cylinder, a rack and pinion mechanism or springs. When the plug-moving means is composed of springs, as the springs shrink, the resisting force of the plug to the pressure of the injected molten resin increases. Therefore when the resisting force of the plug is required to be uniform, it is preferred to compose the plug-moving means of a hydraulic cylinder, a pneumatic cylinder or a rack and pinion mechanism.

The resisting force of the plug to the pressure of the injected molten resin cannot be uniquely determined since it depends upon a resin used, the melt viscosity of a resin used, the injection pressure of a resin, the injection rate of a resin, etc. When the plug is moved during the injection of the molten resin, it is required to control the movement of the plug so that part of the plug can form part of the cavity. For example, when a hydraulic or pneumatic cylinder is used,

the moving rate of the plug can be easily controlled by controlling the actuation of the cylinder. When other mechanism is employed, the above controlling is carried out.

When a plurality of plugs are used in the present invention, the movement (sliding) of the plugs may be initiated at the same time or at different times, and the plugs may be allowed to arrive at their backward end positions at the same time or at different times, and may be moved at the same moving rate or at different moving rates. The above procedures (timings) may be properly determined depending upon the properties of a resin used and the molding conditions.

The position of the pressurized fluid introducing portion in the mold according to the present invention is not specially limited. The pressurized fluid introducing portion may be provided near the resin injection portion, may be provided far from the resin injection portion, or may be provided in the resin injection portion. The pressurized fluid introducing portion may be provided in the plug in some cases. Further, one pressurized fluid introducing portion may be provided, or a plurality of pressurized fluid introducing portions may be provided. When a plurality of pressurized fluid introducing portions are provided, a partition wall of a resin can be formed within a molded article, and a plurality of hollow structures as paths for the flow of a fluid can be formed within a molded article.

In the mold apparatus of the present invention, and in the fist to fourth aspects of the injection molding process of the present invention, the fluid for the pressurized fluid is preferably a fluid which is in a gaseous or liquid state at room temperature under atmospheric pressure, and which neither reacts with the molten resin nor is mutually mixed with the molten resin. Specific examples of the fluid for the pressurized fluid include gaseous substances at room temperature such as nitrogen gas, carbon dioxide gas, air and helium gas, liquids such as water, and gas which is liquefied under high pressure. Above all, inert gases such as nitrogen gas and helium gas are preferred.

The resin used in the injection molding process of the present invention is not specially limited. The resin includes synthetic resins which can be injection-molded, specifically, thermoplastic resins, thermoplastic elastomers, alloys of these and thermosetting resins. Further, the resin includes mixtures of any one of the above resins with known additives such as a stabilizer, a filler and a fibrous reinforcing material such as a glass fiber. Particularly preferred are thermoplastic resins, thermoplastic elastomers, alloys of these, and mixtures of any one of these with an additive such as a stabilizer, a filler and a fibrous reinforcing material. Specific examples of the above resin include generally used thermoplastic resins such as a polyolefin resin, a polystyrene resin, an ABS resin, an AS resin, a PVC resin, a methacrylic resin and a fluorine-containing resin, and engineering plastics such as a polyamide resin, a saturated polyester resin, a polycarbonate resin, a polyacetal resin, a polysulfone resin and a modified polyphenylene ether resin.

The molded article obtained by the injection molding method of the present invention includes a cylinder, a rod, a straight tube and a curved tube a hollow structure. Further, the form of the molded article includes a T-letter form (see schematic cross-sectional views in FIGS. 28B and 28C), a cross or "+" shaped form (see schematic cross-sectional views in FIG. 17B), a Y-letter form (see a schematic cross-sectional view in FIG. 32A), a U-letter like form in which a tube is branching from the bottom of U-letter (see a schematic cross-sectional view in FIG. 32B), an S-letter like form (see a schematic cross-sectional view in FIG. 32C), and a form having radially extending branches (see a schematic plan view in FIG. 33A and a schematic front view in FIG. 33B). Specific examples of the molded article include parts for an automobile and a motorcycle such as a cooling tubing member for an engine, an intake manifold member of an engine, an exhaust gas tubing member and a hydraulic tubing member for a braking device, parts for electric appliances and machines such as a coolant tubing member for a refrigerator and a fluid-controlled actuator tubing member, parts used in the fields of construction and construction materials such as a tubing member for a hot-water heater, a tubing member for a boiler, a tubing member for water supply, a tubing member for gas supply and a shower head, and parts used in the field of medicine such as a tubing member for a medical apparatus for a circulatory system or a tubing member for a medical apparatus for a respiratory system in the field of medicine. The cross section of the molded article, taken nearly at right angles with the flow-axis direction of the molten resin, may have any form of a circular form, an ellipsoidal form, a square form, a polygonal form and others.

In the present invention, the plug is positioned in its forward end position with the plug-moving means, before the molten resin is injected. By maintaining the plug in its forward end position as described above, the molten resin injected into the cavity collides with the plug so that the molten resin is prevented from flowing straight. As a result, jetting can be effectively prevented, and a molded article having an excellent appearance can be obtained.

Further, the volume of the cavity when the molten resin is injected into the cavity is smaller than the volume of the cavity required for finally forming a molded article. Therefore, even when a synthetic resin having a high melt viscosity is used, the formation of a hollow structure can be reliably initiated by introducing the pressurized fluid into the molten resin in the first to fourth aspects of the injection molding process of the present invention. By finally positioning the plug in its backward end position, the cavity form required for forming the molded article is provided so that a desired hollow structure can be easily and reliably formed in the molded article. By gradually expanding the volume of the cavity by moving the plug backwardly, the flow of the molten resin in the cavity can be controlled and a desired hollow structure can be easily and reliably formed in the molded article.

For producing a molded article having a manifold structure of which the branches have different diameters (as shown in FIG. 28C) or cross sectional forms in hollow structure, the initiation and the completion of movements of the plugs and the moving rates of the plugs are controlled so that the degrees of filling the molten resin in each portion of the cavity forming each branch are easily balanced and the movements of the plugs well synchronize with each other when the pressurized fluid is introduced. Therefore, a hollow structure which works, for example, as a path for the flow of a fluid can be easily and reliably formed in the molded article, and the appearance of the molded article is improved. Another advantage is that no weld occurs. Other effects and advantages of the present invention will be apparent from the following description.

BRIEF DESCRIPTION. OF THE DRAWINGS

The present invention will be explained in detail with reference to drawings hereinafter.

FIGS. 1A to 1F and FIGS. 2A to 2D schematically show the timing of movement (sliding) of the plug, the timing of injection of the molten resin, and the timing of introduction of the pressurized fluid.

FIG. 3 is a schematic cross section of one preferred embodiment of the mold apparatus of the present invention, in which the plug is in its backward end position.

FIG. 4 is a schematic cross section of the same embodiment as that of the mold apparatus of the present invention shown in FIG. 3, in which the plug is in its forward end position.

FIG. 5 is a schematic cross section of one preferred embodiment of the mold apparatus of the present invention in which the plug-moving means is composed of a spring.

FIG. 6 is a schematic cross section of one preferred embodiment of the mold apparatus of the present invention in which the plug-moving means is composed of a rack and a pinion mechanism.

FIG. 7 is a schematic cross section of one preferred embodiment of the mold apparatus of the present invention for forming a helically threaded portion on an outer surface of a molded article.

FIGS. 8A and 8B are schematic cross sections of one preferred embodiment of the mold apparatus of the present invention for producing a molded article having a T-letter shaped manifold structure.

FIG. 9 is a schematic cross section of another preferred embodiment of the mold apparatus of the present invention for producing a molded article having a T-letter shaped manifold structure.

FIG. 10 is a schematic cross section of one preferred embodiment of the mold apparatus of the present invention for producing a molded article having a cross or "+" shaped manifold structure.

FIG. 11 is one variation of the mold apparatus shown in FIG. 3.

FIG. 12 is a schematic cross section of a mold apparatus, etc., for the explanation of a step of the injection molding process in Example 1.

FIG. 13 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 1 shown in FIG. 12.

FIG. 14 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 1 shown in FIG. 13.

FIG. 15 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 1 shown in FIG. 14.

FIG. 16 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 1 shown in FIG. 15.

FIG. 17 is a schematic cross section of a molded article produced in Example 1.

FIG. 18 is a schematic cross section of a mold apparatus, etc., for the explanation of a step of the injection molding process in Example 2.

FIG. 19 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 2 shown in FIG. 18.

FIG. 20 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 2 shown in FIG. 19.

FIG. 21 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 2 shown in FIG. 20.

FIG. 22 is a schematic cross section of a mold apparatus, etc., for the explanation of a step of the injection molding process in Example 3.

FIG. 23 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 3 shown in FIG. 22.

FIG. 24 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 3 shown in FIG. 23.

FIG. 25 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 3 shown in FIG. 24.

FIGS. 26A and 26B are schematic cross sections of a mold apparatus, etc., for the explanation of a step of the injection molding process in Example 4.

FIG. 27 is also a schematic cross section of a mold apparatus, etc., for the explanation of a step subsequent to the step of the injection molding process in Example 4 shown in FIG. 26B.

FIGS. 28A to 28C are schematic cross sections of molded articles produced in Example 4.

FIGS. 29A and 29B are schematic cross sections of a mold apparatus, etc., for the explanation of steps of the injection molding process in Example 5.

FIGS. 30A and 30B are schematic cross sections of a mold apparatus, etc., for the explanation of steps subsequent to the step of the injection molding process in Example 5 shown in FIG. 29B.

FIGS. 31A and 31B are schematic cross sections of a mold apparatus, etc., for the explanation of steps of the injection molding process in Example 6.

FIGS. 32A to 32C are schematic cross sections of molded articles produced according to the injection molding process of the present invention.

FIGS. 33A and 33B are schematic cross sections of molded articles produced according to the injection molding process of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be explained with reference to Examples and drawings hereinafter, while the present invention shall not be limited to these Examples. In Figures, the same reference numeral refers to the same part or component.

FIGS. 3 and 4 show schematic cross section of one embodiment of the mold apparatus of the present invention. The mold apparatus shown in FIGS. 3 and 4 has a mold 10 provided with a cavity 16, and is used with an injection molding machine, in which a pressurized fluid is introduced into a molten resin in the cavity 16 while or after the molten resin is injected into the cavity 16, and the molten resin is cooled and solidified in the cavity 16 to form a molded article having a hollow structure. The mold apparatus at least has at least one plug 20, which is provided in the cavity 16 and is movable nearly in parallel with the flow-axis direction of the molten resin, and a plug-moving means 22 for moving

the plug **20**. Further, the mold apparatus has a resin injection portion **12** for injecting a molten resin into the cavity **16** and a pressurized fluid introducing portion **14** for introducing a pressurized fluid into the molten resin injected into the cavity **16**. The plug **20** has a contact surface **20A** (see FIG. 3) which is brought into contact with the molten resin. The contact surface **20A** is generally plated with hard chromium and mirror-finished so that it has a central line average roughness of 0.1 S or less. The plug **20** may be formed. e.g., from the same material as that of the mold **10**. The plug **20** in FIG. 3 is in its backward end position, and the plug **20** in FIG. 4 is in its forward end position. The plug **20** in its forward end position is close to the resin injection portion **12**, and is positioned facing the resin injection portion **12**.

The mold apparatus shown in FIGS. 3 and 4 is provided with one plug **20** and one plug-moving means **22**. The plug **20** is connected to the plug-moving means **22** with a connecting rod **24** which is movable by the actuation of the plug-moving means **22**. The plug-moving means **22** is composed of, for example, a pneumatic cylinder which works, e.g., with compressed air. Reference numeral **40** indicates a solenoid for loading the pressure of compressed air on the plug-moving means **22**, reference numeral **42** indicates a pressure control valve, reference numeral **44** indicates a flow control valve for controlling the moving rate of the plug **20**, and the actuation of the plug-moving means **22** is controlled by the solenoid **40**, the pressure control valve **42** and the flow control valve **44**.

In FIGS. 3 and 4, reference numeral **18** is a cylinder of an injection molding machine. The mold apparatus shown in FIGS. 3 and 4 has a structure in which a molten resin is injected into the cavity **16** from the cylinder **18** of the injection molding machine through the resin injection portion **12**.

In FIGS. 3 and 4, reference numeral **14A** is a pressurized fluid introducing device. The mold apparatus shown in FIGS. 3 and 4 has a structure in which a pressurized fluid is introduced into a molten resin in the cavity **16** from the pressurized fluid introducing device **14A** through the pressurized fluid introducing portion **14** after or while the molten resin is injected into the cavity **16** from the cylinder **18** of an injection molding machine through the resin injection portion **12**. The form of the cavity **16** of the mold **10** defines the outer form of a molded article. On the other hand, the cavity **16** may be designed to allow a molded article to have a extended portion extending from the form of the molded article. In this case, the resin injection portion **12** and the pressurized fluid introducing portion **14** can be provided in that portion of the cavity which corresponds to the extended portion. And, the length of the extended portion from the molded article can be properly determined. The mold apparatus shall not be limited to the above structure, and can be properly design-changed as required.

When the mold apparatus shown in FIGS. 3 and 4 is used, there can be produced a molded article having a hollow structure such as a cylinder or a square pillar having a hollow structure.

FIGS. 5, 6 and 7 show schematic cross sections of other embodiments of the mold apparatus of the present invention.

FIG. 5 shows a mold apparatus similar to the mold apparatus shown in FIG. 3, and the mold apparatus shown in FIG. 5 has a plug-moving means **22** composed of a spring.

FIG. 6 shows a mold apparatus having a plug-moving means **22** composed of a rack and pinion mechanism having a rack **50** and a pinion gear **52**. The toothed portions of the rack **50** and the pinion gear **52** are omitted. One end of the rack **50** is connected to a connecting rod **24**. The pinion gear **52** is rotated with a motor (not shown), and when the pinion gear **52** is rotated, the connecting rod **24** connecting the rack **50** and a plug **20** are moved. The above mold structure enables the production of a curved tube having an arc form. FIG. 6 omits a cylinder **18** of an injection molding machine.

A molded article may have an outer surface formed to have a design or a functional portion thereon. In a mold apparatus shown in FIG. 7, the cavity surface of a cavity **16** has a concave portion **16A** so that a molded article has an outer surface having a spiral threaded portion. In this case, it is preferred that the outer diameter of a plug **20** be smaller than the diameter of a bottom portion of the threaded portion of the molded article, that the length of the plug **20** be greater than the length of the threaded portion as a whole, and that the movement distance of the plug **20** be greater than the length of the threaded portion as a whole.

FIGS. 8A, 8B, 9 and 10 show schematic cross sections of other embodiments of the mold apparatus of the present invention. In these Figures, a cylinder **18** and a pressurized fluid introducing device **14A** are omitted. In the mold apparatus shown in these Figures, a pressurized fluid introducing portion **14** is provided apart from a resin injection portion **12**. The pressurized fluid introducing device may be, for example, a gas ejection nozzle equipped with a non-return valve. A cavity **16** is designed such that a molded article has a extended portion extending from the molded article, and the resin injection portion **12** and the pressurized fluid introducing portion **14** are provided in that portion of the cavity which corresponds to the above extended portion.

The mold apparatus shown in FIG. 8A has two plugs **20A** and **20B** and two plug-moving means **22A** and **22B**. The mold apparatus shown in FIG. 8B has one plug **20** and one plug-moving means **22**. The mold apparatus shown in FIGS. 9 and 10 have three plugs **20A**, **20B** and **20C** and three plug-moving means **22A**, **22B** and **22C**, and the plugs are connected to the corresponding plug-moving means with connecting rods **24A**, **24B** and **24C** which are movable by the actuation of the corresponding plug-moving means **22A**, **22B** and **22C**. The plug-moving means is composed, e.g., of a hydraulic cylinder which works under an oil pressure.

When the mold apparatus shown in FIGS. 8A, 8B and 9 are used, molded articles having a T-letter shaped manifold structure shown in FIGS. 28B and 28C can be produced. The molded articles have a T-letter shaped hollow structure **32**, e.g., as a path for the flow of a fluid. When the mold shown in FIG. 10 is used, a molded article having a cross or "+" shaped hollow structure shown in FIG. 17B can be produced. The molded article has a cross or "+" shaped hollow structure **32**, e.g., as a path for the flow of a fluid.

In the mold apparatus shown in FIGS. 3 and 4, the pressurized fluid introducing portion **14** and the resin injection portion **12** are provided substantially in the same place. In a mold apparatus shown in FIG. 11, a pressurized fluid introducing portion **14** and a resin injection portion **12** are provided in different places in the mold apparatus.

The injection molding process of the present invention will be specifically explained with reference to Examples hereinafter.

EXAMPLE 1

Example 1 relates to the first aspect of the injection molding process of the present invention, and uses the mold apparatus shown in FIG. 10 for producing a molded article having a cross or "+" shaped hollow structure. The molded article has a cross or "+" shaped hollow structure **32** which

works, e.g., as paths for the flow of a fluid, as shown in FIG. 17B. In Example 1, after the completion of the injection of a molten resin 30 from the resin injection portion 12 into the cavity 16, a pressurized fluid is introduced from the pressurized fluid introducing portion 14 into the molten resin 30 in the cavity 16. The molten resin is then cooled and solidified in the cavity 16 to form a molded article of the resin 30A having the hollow structure 32. In Example 1, during the injection of the molten resin 30, the plug 20A is moved nearly in parallel with the flow-axis direction of the molten resin 30 toward its backward end position. Further, while the plugs 20A, 20B and 20C are moved, the pressurized fluid is injected into the molten resin 30 in the cavity 16, and finally, the plugs 20A, 20B and 20C are moved nearly in parallel with the flow-axis direction of the molten resin 30 and arrive at their backward end positions during the introduction of the pressurized fluid.

The injection molding process in Example 1 will be explained hereinafter with reference to FIGS. 10 and 12 to 16 which show schematic cross sections of a mold apparatus, etc., FIG. 1C which is a timing chart and FIG. 17 which shows a schematic cross section of a molded article. In FIGS. 12 to 16, the cylinder of an injection molding machine, the pressurized fluid introducing device, the solenoid, the pressure control valve, etc., are omitted.

Each of the plug-moving means 22A, 22B and 22C was composed of a hydraulic cylinder having a piston diameter of 30 mm, which was to work hydraulically. The distance of movement (sliding) of the plug 20A was set at 100 mm. The distance of movement (sliding) of each of the plugs 20B and 20C was set at 50 mm. A polyphenylene sulfide resin (trade name "NOVAPPS 704G40", glass fiber-reinforced grade, supplied by Mitsubishi Engineering-Plastics Corp.) was plasticized and melted in the cylinder of the injection molding machine (not shown) at 320° C. The mold temperature was set at 130° C.

First, the mold 10 was clamped, and then the plugs 20A, 20B and 20C were allowed to stand in their forward end positions against the pressure of a molten resin to be injected, with the plug-moving means 22A, 22B and 22C before the molten resin was injected (see FIG. 10). Each of the plug-moving means 22A, 22B and 22C, each of which was composed of a hydraulic cylinder, was provided with an oil pressure of 100 kgf/cm^2 as a resisting force against the pressure of the molten resin to be injected.

Then, the molten resin 30 was injected into the cavity 16 through the resin injection portion 12 provided in the mold 10 (see FIG. 12). The injection pressure was set at 500 kgf/cm^2, and the injection rate was set at 70 cm^3/second. Immediately after the initiation of the injection of the molten resin 30 into the cavity 16, the plug-moving means 22A was actuated to move the plug 20A nearly in parallel with the flow-axis direction of the molten resin toward its backward end position. The plugs 20B and 20C were maintained in their forward end positions with the plug-moving means 22B and 22C. After the plug 20A moved at a predetermined distance, the movement of the plugs 20B and 20C toward their backward end positions was initiated with the plug-moving means 22B and 22C.

The injection of the molten resin 30 into the cavity 16 was continued, and when the plug 20A was moved back at a distance of 70 mm and when the plugs 20B and 20C were moved back at a distance of 25 mm (1.6 seconds after the injection of the molten resin was initiated) as shown in FIG. 13, the injection of the molten resin was completed. Immediately after the completion of the injection of the molten resin, a pressurized fluid which was a compressed nitrogen gas having a pressure of 100 kgf/cm^2 was introduced into the molten resin 30 through the pressurized fluid introducing portion 14, and at the during the introduction of the pressurized fluid, the plugs 20A, 20B and 20C were moved with the plug-moving means 22A, 22B and 22C (see FIGS. 14 and 15) until these plugs arrived at their backward end positions (see FIG. 16). As a result, a hollow structure 32 was formed in the molten resin 30.

The pressurized fluid was maintained under a predetermined pressure for 70 seconds in the dwell period, and further, the molten resin was cooled for 20 seconds. Then, the pressurized fluid in the hollow structure 32 was released to atmosphere through the pressurized fluid introducing portion 14. Then, the mold was opened, and a molded article was taken out. FIG. 17A shows a schematic cross section of the molded article. Portions indicated by chain lines in FIG. 17A were removed to give a molded article formed of the resin 30A as a product as shown in FIG. 17B. The molded article had a cross or "+" shaped manifold structure. The molded article had a cross or "+" shaped hollow structure 32, e.g., as a path for the flow of a fluid and had an excellent appearance. When the plugs 20A, 20B and 20C are moved until they are out of that portion of the cavity 16 which defines the outer form of the molded article, then, a molded article shown in FIG. 17C is obtained. When the extended portions indicated by chain lines in FIG. 17C are removed, the hollow structure 32, e.g., as a path for the flow of a fluid, can be reliably and easily formed.

COMPARATIVE EXAMPLE 1

A molded article having a cross or "+" shaped manifold structure was produced in the same manner as in Example 1 except that the plugs 20A, 20B and 20C were positioned in their backward end positions from the beginning. As a result, jetting occurred in a molten resin injected into the cavity of the mold, and the molded article had no desired hollow structure.

EXAMPLE 2

Example 2 also relates to the first aspect of the injection molding process of the present invention, and uses a mold apparatus shown in FIGS. 3 and 4 for producing a cylindrical molded article having a hollow structure 32.

The injection molding process in Example 2 will be explained hereinafter with reference to FIGS., 4 and 18 to 21 which show schematic cross sections of a mold apparatus, etc., and FIG. 1C which is a timing chart. In FIGS. 18 to 21, the cylinder of an injection molding machine, the pressurized fluid injection device, the solenoid, the pressure control valve, etc., are omitted.

The plug-moving means 22 was composed of a pneumatic cylinder having a piston diameter of 30 mm, which was to work with compressed air. The distance of movement of the plug 20 was set at 200 mm. A polyacetal resin having a high molecular weight (trade name "Iupital F10", natural color, supplied by Mitsubishi Engineering-Plastics Corp.) was plasticized and melted in the cylinder 18 of an injection molding machine (see FIG. 4) at a resin temperature of 200° C. The mold temperature was set at 30° C. In FIG. 4, the molten resin in the cylinder 18 is omitted.

First, the mold 10 was clamped, and then, before the injection of a molten resin, the plug 20 was positioned in its forward end position in the cavity 16 with the plug-moving means 22 (see FIG. 4). The plug-moving means 22, which was composed of a pneumatic cylinder, was provided with

a compressed air pressure of 5 kgf/cm^2. The fluid control pressure of the pressure control valve **42** was set at 7 kgf/cm^2.

Then, the molten resin **30** was injected into the cavity **16** through the resin injection portion **12** provided in the mold **10** (see FIG. **18**). The injection pressure was set at 800 kgf/cm^2, and the injection rate was set at 70 cm^3/second. The plug **20** had a resisting force against the pressure of the injected molten resin, provided by the plug-moving means **22**. However, since the force of the molten resin under the injection pressure was greater than the resisting force, the plug **20** began to move nearly in parallel with the flow-axis direction of the molten resin toward its backward end position under the pressure of the injected molten resin, which state is shown in FIG. **19**.

The injection of the molten resin was completed 1.7 seconds after the injection of the molten resin was initiated. Immediately thereafter, a pressurized fluid which was a compressed nitrogen gas having a pressure of 100 kgf/cm^2 was introduced into the molten resin **30** through the pressurized fluid introducing portion **14**, and at the same time, the solenoid **40** (see FIG. **4**) was switched to move the plug **20** with the plug-moving means **22** (see FIG. **20**). The plug **20** was further moved and it arrived at its backward end position (see FIG. **21**) by the plug-moving means **22**. As a result, the hollow structure **32** was formed in the molten resin **30**.

The pressurized fluid was maintained at a predetermined pressure for **50** seconds in the dwell period. After the resin was cooled for a predetermined period of time, the pressurized fluid in the hollow structure **32** was released into atmosphere through the pressurized fluid introducing portion **14**. Then, the mold was opened, and a molded article was taken out. The molded article had a desired hollow structure, and its outer surface had no defect caused by jetting so that the molded article had an excellent appearance.

COMPARATIVE EXAMPLE 2

A molded article was produced in the same manner as in Example 2 except that the plug **20** was fixed in its backward end position. As a result, the outer surface of the molded article had defects caused by jetting.

EXAMPLE 3

Example 3 also relates to the first aspect of the injection molding process of the present invention, and uses a mold apparatus of which the plug-moving means **22** is composed of a spring as shown in FIG. **5**.

The injection molding process in Example 3 will be explained hereinafter with reference to FIGS. **5** and **22** to **25** showing schematic cross sections of the mold apparatus, etc. In FIGS. **22** to **25**, the cylinder of an injection molding machine and the pressurized fluid injection device are omitted.

The distance of movement of the plug **20** was set at 200 mm. The plug-moving means **22** was composed of a spring, and the spring had an energizing force of 20 kgf in the forward end position of the plug **20** and an energizing force of 50 kgf in the backward end position of the plug **20**. The same resin as that used in Example 2 was injection-molded under the same conditions as those in Example 2.

First, the mold **10** was clamped, and before the injection of a molten resin was initiated, the plug **20** was maintained in its forward end position in the cavity **16** with the plug-moving means **22** (see FIG. **5**). Then, the molten resin **30** was injected into the cavity **16** through the resin injection portion **12** provided in the mold **10** (see FIG. **22**). The injection pressure was set at 1200 kgf/cm^2, and the injection rate was set at 70 cm^3/second. The plug **20** had a resisting force against the pressure of the injected molten resin, provided by the plug-moving means **22**. However, since the force of the molten resin under the injection pressure was greater than the resisting force, the plug **20** began to move nearly in parallel with the flow-axis direction of the molten resin toward its backward end position under the pressure of the injected molten resin, which state is shown in FIG. **23**.

The injection of the molten resin **30** was completed 1.7 seconds after the injection of the molten resin **30** through the resin injection portion **12** was initiated. Immediately thereafter, a pressurized fluid which was a compressed nitrogen gas having a pressure of 100 kgf/cm^2 was introduced into the molten resin **30** through the pressurized fluid introducing portion **14**. Under the pressure of the pressurized fluid introduced into the molten resin **30**, the plug **20** was further moved nearly in parallel with the flow-axis direction of the molten resin toward its backward end position (see FIG. **24**). Finally, the plug **20** arrived at its backward end position (see FIG. **25**). As a result, the hollow structure **32** was formed in the molten resin **30**.

The pressurized fluid was maintained at a predetermined pressure for 60 seconds in the dwell period, and after the resin was cooled for a predetermined period of time, the pressurized fluid in the hollow structure **32** was released into atmosphere through the pressurized fluid introducing portion **14**. Then, the mold was opened, and a molded article was taken out. The molded article had a desired hollow structure, and its outer surface had no defect caused by jetting so that the molded article had an excellent appearance.

EXAMPLE 4

Example 4 relates to the fourth aspect of the injection molding process of the present invention, and uses a mold apparatus shown in FIG. **8A** for producing a molded article having a T-letter shaped manifold structure. A T-letter shaped hollow structure **32** which works, e.g., as a path for the flow of a fluid, is formed in the molded article. In Example 4, after the completion of the injection of a molten resin **30** into the cavity **16** through the resin injection portion **12**, a pressurized fluid is introduced into the molten resin **30** in the cavity **16** through the pressurized fluid introducing portion **14**, and the molten resin **30** is cooled and solidified in the cavity **16** to form a molded article of the resin **30A** having the hollow structure **32**. In Example 4, during the injection of the molten resin **30** into the cavity **16**, the plugs **20A** and **20B** are maintained in their forward end positions with the plug-moving means **22A** and **22B**, and after the injection of the molten resin **30** is completed, the pressurized fluid is introduced into the molten resin **30** in the cavity **16**, and at the same time, the plugs **20A** and **20B** are moved nearly in parallel with the flow-axis direction of the molten resin **30** until they arrive at their backward end position.

The injection molding process in Example 4 will be explained hereinafter with reference to FIGS. **8A**, **26** and **27** which show schematic cross sections of a mold apparatus, etc., FIG. **2C** which is a timing chart and FIG. **28** which shows a schematic cross section of a molded article.

Each of the plug-moving means **22A** and **22B** was composed of a hydraulic cylinder having a piston diameter of 30 mm, which was to work under the pressure of an oil. The

distance of movement (sliding) of each of the plugs 20A and 20B was set at 30 mm. A modified PPE resin having a high viscosity (trade name "Iupiace AH110", natural color, supplied by Mitsubishi Engineering-Plastics Corp.) was plasticized and melted in the cylinder of an injection molding machine (not shown) at a resin temperature of 350° C. The mold temperature was set at 100° C.

First, the mold 10 was clamped. Then, before the injection of the molten resin was initiated, the plugs 20A and 20B were maintained in their forward end positions in the cavity 16 with the plug-moving means 22A and 22B so that the plugs 20A and 20B stood against the pressure of the molten resin to be injected (see FIG. 8A). In this case, each of the plug-moving means 22A and 22B, composed of hydraulic cylinders, was provided with an oil pressure of 100 kgf/cm^2 to stand against the pressure of the molten resin to be injected.

Then, the molten resin 30 was injected into the cavity 16 through the resin injection portion 12 provided in the mold 10. The injection pressure was set at 400 kgf/cm^2, and the injection rate was set at 70 cm^3/second. During the injection of the molten resin 30 into the cavity 16, the plugs 20A and 20B were maintained in their forward end positions with the plug-moving means 22A and 22B (see FIG. 26A).

Immediately after the completion of molten resin injection into the cavity 16, a pressurized fluid which was a compressed nitrogen gas having a pressure of 100 kgf/cm^2 was introduced into the molten resin 30 through the pressurized fluid introducing portion 14. At the same time, the plugs 20A and 20B were moved nearly in parallel with the flow-axis direction of the molten resin with the plug-moving means 22A and 22B until they arrived at their backward end positions. FIG. 26B schematically shows a state of the plugs 20A and 20B which were being moved, and FIG. 27 schematically shows a state where the plugs 20A and 20B arrived at their backward end positions.

The pressurized fluid was maintained at a predetermined pressure for 70 seconds in the dwell period, and the resin was cooled for 10 seconds. Then, the pressurized fluid in the hollow structure 32 was released into atmosphere through the pressurized fluid introducing portion 14. Then, the mold was opened, and a molded article was taken out. FIG. 28A shows a schematic cross section of the molded article. Portions indicated by chain lines in FIG. 28A were removed to obtain a molded article of the resin 30A as a product shown in FIG. 28B. The molded article had a T-letter shaped manifold structure, and had a T-letter shaped hollow structure 32, e.g., as a path for the flow of a fluid.

COMPARATIVE EXAMPLE 3

A molded article having a T-letter shaped manifold structure was produced in the same manner as in Example 4 except that the plugs 20A and 20B were fixed in their backward end positions. As a result, no uniform hollow structure was formed in the molded article.

EXAMPLE 5

Example 5 relates to the second aspect of the injection molding process of the present invention, and uses a mold apparatus shown in FIG. 8B for producing a molded article having a T-letter shaped manifold structure. In the molded article, a T-letter shaped hollow structure 32, e.g., as a path for the flow of a fluid is formed. In Example 5, after the completion of the injection of a molten resin into the cavity 16 through the resin injection portion 12, a pressurized fluid is introduced into the molten resin 30 in the cavity 16 through the pressurized fluid introducing portion 14, and the molten resin is cooled and solidified in the cavity 16 to form a molded article of the resin 30A having the hollow structure 32. During the injection of the molten resin 30, the plug 20 is moved nearly in parallel with the flow-axis direction of the molten resin toward its backward end position with the plug-moving means 22, and during the injection of the molten resin, the plug 20 arrives at its backward end position. Then, the pressurized fluid is introduced into the molten resin 30 in the cavity 16.

The injection molding process in Example 5 will be explained hereinafter with reference to FIGS., 8B, 29 and 30 which show schematic cross sections of a mold apparatus, etc., and FIG. 1E which is a timing chart. The plug-moving means 22 was composed of a hydraulic cylinder having a piston diameter of 30 mm, which was to work under an oil pressure. The distance of movement (sliding) of the plug 20 was set at 50 mm.

First, the mold 10 was clamped, and then, before the injection of the molten resin was initiated, the plug 20 was maintained in its forward end position in the cavity 16 with the plug-moving means 22 (see FIG. 8B).

Then, the molten resin 30 was injected into the cavity 16 through the resin injection portion 12 provided in the mold 10 (see FIG. 29A). While the injection of the molten resin 30 into the cavity 16 was continued, the plug 20 was moved nearly in parallel with the flow-axis direction of the molten resin 30 toward its backward end position with the plug-moving means 22, and during the injection of the molten resin, the plug 20 arrived at its backward end position. Then, the injection of the molten resin 30 into the cavity 16 was completed (see FIG. 29B).

Immediately after the injection of the molten resin was completed, a pressurized fluid was introduced into the molten resin 30 through the pressurized fluid introducing portion 14 (see FIG. 30A). The pressurized fluid was maintained at a predetermined pressure for 70 seconds in the dwell period, and then the resin was cooled for 5 seconds, which state is schematically shown in FIG. 30B. Then, the pressurized fluid in the hollow structure 32 was released into atmosphere through the pressurized fluid introducing portion 14. Then, the mold was opened, and a molded article was taken out. FIG. 28A shows a schematic cross section of the molded article. Portions indicated by chain lines in FIG. 28A were removed to obtain a molded article of the resin 30A shown in FIG. 28B. The molded article had a T-letter shaped manifold structure, and had a T-letter shaped hollow structure 32, e.g., as a path for the flow of a fluid.

EXAMPLE 6

Example 6 relates to the third aspect of the injection molding process of the present invention, and uses a mold apparatus almost similar to the mold apparatus shown in FIG. 8A for producing a molded article having a T-letter shaped manifold structure. A T-letter shaped hollow structure 32, e.g., as a path for the flow of a fluid, is formed in the molded article. In Example 6, during the injection of a molten resin 30 into the cavity 16 through the resin injection portion 12, a pressurized fluid is introduced into the molten resin 30 in the cavity 16 through the pressurized fluid introducing portion 14, and the molten resin 30 is cooled and solidified to form a molded article of the resin 30A having a hollow structure 32. In Example 6, while the pressurized fluid is introduced into the molten resin 30 in the cavity 16 during the injection of the molten resin 30 into the cavity 16, the plugs 20A and 20B are moved nearly in parallel with the

flow-axis direction of the molten resin 30 with the plug-moving means 22A and 22B until the plugs 20A and 20B arrive at their backward end positions.

The injection molding process in Example 6 will be explained hereinafter with reference to FIGS., 8A and 31A and 31B which show schematic cross sections of a mold apparatus, etc., and FIG. 2B which is a timing chart. Each of the plug-moving means 22A and 22B was composed of a hydraulic cylinder having a piston diameter of 30 mm, which was to work under an oil pressure. The distance of movement (sliding) of each of the plugs 20A and 20B was set at 50 mm.

First, the mold 10 was clamped, and then, before the injection of a molten resin, the plugs 20A and 20B were maintained in their forward end positions with the plug-moving means 22A and 22B (see FIG. 8A).

Then, the molten resin 30 was injected into the cavity 16 through the resin injection portion 12 provided in the mold 10. During the injection of the molten resin 30 into the cavity 16, the introduction of the pressurized fluid in the molten resin 30 in the cavity 16 was initiated (see FIG. 31A).

Then, while the molten resin 30 was injected into the cavity 16 with introducing the pressurized fluid into the molten resin 30 in the cavity 16, the plugs 20A and 20B were moved nearly in parallel with the flow-axis direction of the molten resin 30 with the plug-moving means 22A and 22B until the plugs 20A and 20B arrived at their backward end positions. The introduction of the pressurized fluid was continued after the completion of the injection of the molten resin 30. FIG. 31B shows a schematic cross section of the plugs 20A and 20B which were being moved. The state where the plugs 20A and 20B arrived at their backward end positions is almost the same as that shown in FIG. 27.

The pressurized fluid was maintained at a predetermined pressure for 80 seconds in the dwell period, and the resin was cooled for 5 seconds. Then, the pressurized fluid in the hollow structure 32 was released into atmosphere through the pressurized fluid introducing portion 14. Then, the mold was opened, and a molded article was taken out. The molded article had a cross section as schematically shown in FIG. 28A.

The present invention is explained hereinabove with reference to preferred Examples, while the present invention shall not be limited to those Examples. The structures of the mold apparatus, the various conditions for the injection molding process, and the resins used in Examples are described by way of examples, and may be changed as required. For example, the numbers and positions of resin injection portions and pressurized fluid introducing portions are described by way of examples, and may be changed as required. The plug(s) may be moved with the plug-moving means or may be moved with the pressure of a molten resin and/or a pressurized fluid introduced into the molten resin, or may be moved with the plug-moving means and the pressure of a molten resin and/or a pressurized fluid introduced into the molten resin. The mold apparatus of the present invention having no pressurized fluid introducing portion enables the production of a molded article having a solid structure, and in this case, the occurrence of jetting in a molten resin injected into a cavity can be effectively prevented.

According to the present invention, the occurrence of jetting in a molten resin injected into the cavity of a mold can be effectively prevented, and, as a result, a molded article having an excellent appearance can be obtained. In a conventional mold apparatus having a resin injection portion on the upper cavity surface, jetting is liable to occur since a molten resin is affected by gravity when the molten resin is injected into the cavity. The present invention uses plug(s), so that a molten resin is hardly affected by gravity when the molten resin is injected into the cavity. Therefore, the resin injection portion may be provided in any place in a mold, which increases the freedom of design of a mold apparatus.

Further, according to the present invention, a molded article having a hollow structure can be easily and reliably produced from a synthetic resin having a high melt viscosity. For a molded article having a hollow structure in which hollow branches have different diameters or different cross sections, a hollow structure, e.g., as a path for the flow of a fluid, can be reliably produced. Furthermore, a molded article has an improved appearance. Moreover, the present invention enables the production of a molded article having a complicated hollow structure as one product, so that the production cost can be decreased and that the steps of bonding or welding parts can be omitted. The productivity is therefore improved.

According to the present invention, there can be easily produced a molded article having a T-letter shaped hollow structure, a cross or "+" shaped hollow structure or a more complicated hollow structure, e.g., as a path for the flow of a fluid. Therefore, molded articles having a hollow structure, produced by the present invention, can be used as a tubing member in the fields of automobiles, motorcycles, electric appliances, machinery construction and medicine, and inexpensive molded articles can be provided.

What is claimed is:

1. A mold apparatus having a mold provided with a cavity, for use with an injection molding machine, for producing a tubular molded article having a hollow structure by introducing a pressurized fluid into a molten resin in the cavity while or after the molten resin is injected into the cavity, and cooling and solidifying the molten resin in the cavity to form a hollow structure in the tubular molded article in parallel with an axis thereof, said mold apparatus comprising

(A) at least one plug which is provided in the cavity of the mold and is movable in parallel with the axis of the tubular molded article and in parallel with parting lines of the mold from a forward end position to a backward end position, for changing an effective volume of the cavity,

(B) a plug-moving means for moving the plug,

(C) a resin injection portion for injecting the molten resin into the cavity, and

(D) a pressurized fluid introducing portion for introducing the pressurized fluid into the molten resin injected into the cavity;

wherein the plug has a top end portion and the plug is positioned so that the top end portion is positioned close to the resin injection portion when the plug is in the forward end position.

2. The mold apparatus of claim 1, wherein the plug-moving means is composed of a hydraulic cylinder or a pneumatic cylinder.

3. The mold apparatus of claim 1, wherein the plug-moving means is composed of a spring.

4. The mold apparatus of claim 1, wherein the plug-moving means is composed of a rack and pinion mechanism.

5. A process for the production of a tubular molded article having a hollow structure, using an injection molding machine equipped with a mold apparatus having a mold provided with a cavity, said mold apparatus comprising

(A) at least one plug which is provided in the cavity of the mold and is movable in parallel with an axis of the

tubular molded article and in parallel with parting lines of the mold from a forward end position to a backward end position, for changing an effective volume of the cavity,

(B) a plug-moving means for moving the plug,

(C) a resin injection portion for injecting the molten resin into the cavity, and

(D) a pressurized fluid introducing portion for introducing a pressurized fluid into the molten resin injected into the cavity,

wherein the plug has a top end portion and the plug is positioned that the top end portion is positioned close to the resin injection portion when the plug is in the forward end position,

by introducing the pressurized fluid into the molten resin in the cavity of the mold throuhg the pressurized fluid introducing portion while or after the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the tubular molded article in the parallel with the axis thereof,

said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity by the plug-moving means before the molten resin is injected,

(b) moving the plug toward its backward end position in parallel with the axis of the tubular molded article and in parallel with the parting lines of the mold, by the plug-moving means or under a pressure of the injected molten resin, after the injection of the molten resin is initiated,

(c) introducing the pressurized fluid into the molten resin in the cavity through the pressurized fluid introducing portion while the plug is moving, and

(d) moving the plug up to its backward end position in parallel with the axis of the tubular molded article and in parallel with the parting lines of the mold, by the plug-moving means or under the pressure of the molten resin and/or the pressurized fluid introduced into the molten resin, and then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

6. The process of claim 5, wherein the plug-moving means is composed of a hydraulic cylinder or a pneumatic cylinder.

7. The process of claim 5, wherein the plug-moving means is composed of a spring.

8. The process of claim 5, wherein the plug-moving means is composed of a rack and pinion mechanism.

9. The process of claim 5, wherein the molded article has a manifold structure.

10. A process for the production of a tubular molded article having a hollow structure, using an injection molding machine equipped with a mold apparatus having a mold provided with a cavity, said mold apparatus comprising

(A) at least one plug which is provided in the cavity of the mold and is movable in parallel with an axis of the tubular molded article and in parallel with parting lines of the mold from a forward end position to a backward end position, for changing an effective volume of the cavity,

(B) a plug-moving means for moving the plug,

(C) a resin injection portion for injecting the molten resin into the cavity, and

(D) a pressurized fluid introducing portion for introducing a pressurized fluid into the molten resin injected into the cavity,

wherein the plug has a top end portion and the plug is positioned so that the top end portion is positioned close to the resin injection portion when the plug is in the forward end position,

by introducing the pressurized fluid into the molten resin in the cavity of the mold through the pressurized fluid introducing portion while or after the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the tubular molded article in parallel with the axis thereof,

said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity by the plug-moving means before the molten resin is injected,

(b) moving the plug toward its backward end position in parallel with the axis of the tubular molded article and in parallel with the parting lines of the mold, by the plug-moving means or under a pressure of the injected molten resin, after the injection of the molten resin is initiated, and allowing the plug to arrive at its backward end position during the injection of the molten resin or after the injection of the molten resin is completed,

(c) introducing the pressurized fluid into the molten resin in the cavity through the pressurized fluid introducing portion, and

(d) then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

11. The process of claim 10, wherein the plug-moving means is composed of a hydraulic cylinder or a pneumatic cylinder.

12. The process of claim 10, wherein the plug-moving means is composed of a spring.

13. The process of claim 10, wherein the plug-moving means is composed of a rack and pinion mechanism.

14. The process of claim 10, wherein the molded article has a manifold structure.

15. A process for the production of a tubular molded article having a hollow structure, using an injection molding machine equipped with a mold apparatus having a mold provided with a cavity, said mold apparatus comprising

(A) at least one plug which is provided in the cavity of the mold and is movable in parallel with an axis of the tubular molded article and in parallel with parting lines of the mold from a forward end position to a backward position, for changing an effective volume of the cavity,

(B) a plug-moving means for moving the plug,

(C) a resin injection portion for injecting the molten resin into the cavity, and

(D) a pressurized fluid introducing portion for introducing a pressurized fluid into the molten resin injected into the cavity,

wherein the plug has a top end portion and the plug is positioned so that the top end portion is positioned close to the resin injection portion when the plug is in the forward end position,

by introducing the pressurized fluid into the molten resin in the cavity of the mold through the pressurized fluid introducing portion while the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the tubular molded article in parallel with the axis thereof,

said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity by the plug-moving means before the molten resin is injected,

(b) moving the plug toward its backward end position in parallel with the axis of the tubular molded article and in parallel with the parting lines of the mold, by the plug-moving means or under a pressure of the injected molten resin and/or a pressure of the pressurized fluid introduced into the molten resin, while the molten resin is injected into the cavity and while the pressurized fluid is introduced into the molten resin, and allowing the plug to arrive at its backward end position during the introduction of the pressurized fluid, and

(c) then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

16. The process of claim 15, wherein the plug-moving means is composed of a hydraulic cylinder or a pneumatic cylinder.

17. The process of claim 15, wherein the plug-moving means is composed of a spring.

18. The process of claim 15, wherein the plug-moving means is composed of a rack and pinion mechanism.

19. The process of claim 15, wherein the molded article has a manifold structure.

20. A process for the production of a tubular molded article having a hollow structure, using an injection molding machine equipped with a mold apparatus having a mold provided with a cavity, said mold apparatus comprising

(A) at least one plug which is provided in the cavity of the mold and is movable in parallel with an axis of the tubular molded article and in parallel with parting lines of the mold from a forward end position to a backward end position, for changing an effective volume of the cavity,

(B) a plug-moving means for moving the plug,

(C) a resin injection portion for injecting the molten resin into the cavity, and

(D) a pressurized fluid introducing portion for introducing a pressurized fluid into the molten resin injected into the cavity,

wherein the plug has a rod end portion and the plug is positioned so that the top end portion is positioned close to the resin injection portion when the plug is in the forward end position,

by introducing the pressurized fluid into the molten resin in the cavity of the mold through the pressurized fluid introducing portion after the molten resin is injected into the cavity through the resin injection portion, and cooling and solidifying the resin in the cavity to form a hollow structure in the tubular molded article in parallel with the axis thereof,

said process comprising the steps of

(a) positioning the plug in its forward end position in the cavity so as to allow the plug to stand against a pressure of the molten resin to be injected, by the plug-moving means before the molten resin is injected,

(b) maintaining the plug in its forward end position by the plug-moving means during the injection of the molten resin through the resin injection portion,

(c) moving the plug toward its backward end position in parallel with the axis of the tubular molded article and in parallel with the parting lines of the mold, by the plug-moving means or under a pressure of the pressurized fluid, after the injection of the molten resin is completed and after or before the introduction of pressurized fluid is initiated, and allowing the plug to arrive at its backward end position during the introduction of the pressurized fluid, and

(d) then, cooling and solidifying the molten resin in the cavity to form the hollow structure in the resin.

21. The process of claim 20, wherein the plug moving means is composed of a hydraulic cylinder or a pneumatic cylinder.

22. The process of claim 20, wherein the plug moving means is composed of a spring.

23. The process of claim 20, wherein the plug moving means is composed of a rack and pinion mechanism.

24. The process of claim 20, wherein the molded article has a manifold structure.

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